# TORNADO FORECASTING AND SEVERE STORM WARNING

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## HEARING

BEFORE THE

SUBCOMMITTEE ON NATURAL RESOURCES,
AGRICULTURE RESEARCH AND ENVIRONMENT

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED FIRST CONGRESS

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MARCH 3, 1989

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# TORNADO FORECASTING AND SEVERE STORM WARNING

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FRIDAY, MARCH 3, 1989

House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Natural Resources, Agriculture
Research and Environment,
*Raleigh, North Carolina.*

The subcommittee met, pursuant to call, at 9:38 a.m. in the School Auditorium, Lynn Road Elementary School, Raleigh, North Carolina, Honorable David Price presiding.

Mr. Scheuer. Good morning. I am Congressman Jim Scheuer from New York and I am Chairman of the Subcommittee on Natural Resources, Agriculture Research and Environment of the Science, Space, and Technology Committee.

I want to thank everybody involved and concerned with the very fine welcome that I and my colleagues have received here this morning as we come down here for a very important field Congressional hearing, a hands-on hearing where we talk to local experts and engage your wisdom and your insights into coming up—into producing realistic and practical legislative solutions to major national problems. In this case, the awesome problem of tornado forecasting and severe storm warning.

Now the United States experiences a great deal of severe weather conditions every single year. In fact, we have an average of about 1000 tornadoes every year, which is ten times as many as any other nation on earth enjoys—or is afflicted with. Yet our ability to forecast these severe storms and forecast tornadoes has been crippled by our inability and unwillingness to invest in modern technology.

This Subcommittee authorizes the funding of the National Oceanic and Atmospheric Administration, which we call NOAA, which of course includes the National Weather Service. For a number of years, this Subcommittee has been urging the National Weather Service to get its act together and modernize their equipment, much of which is outdated, outmoded, inadequate, obsolete and represents the technology of the 1950s. So we were particularly disturbed to hear that a severe storm tragedy had afflicted this community, in large part because of our continued reliance on outmoded and outdated equipment.

We expect that this hearing today will provide us much essential guidance as we strive to improve the effectiveness of our National Weather Service.

I am very honored to be here today with two truly outstanding members of Congress, and outstanding members of this Subcommittee that has jurisdiction over weather; Congressman David Price and Congressman Tim Valentine.

Congressman Price is a leader in the Congress in the field of education, in the field of preschool learning, enriched educational opportunity for kids at all ages. And his expertise in this and other matters is very much valued on the Science, Space, and Technology Committee.

Tim Valentine's leadership in the past has been recognized by his colleagues as he has just been elected Chairman of the Subcommittee on Transportation, Aviation and Materials. And I might say that the hearings that Congressman Valentine chaired right in this region, in the Raleigh region, in 1984 absolutely without doubt in my book, improved our emergency preparedness system and procedures and practices, and without a doubt saved many lives, many lives, during the recent tornado outbreak. So I would like to congratulate him on his diligence and his determination to improve the tornado warning system, the severe warning system, and you should know that he has made a very significant contribution already as a result of the hearings he chaired two years ago.

At this time, I would like to turn the gavel and responsibility for chairing this hearing over to Congressman David Price, who represents this district. And I might say you are fortunate to have a man of his caliber representing you in Washington. He and Tim have both won the respect and the high esteem of their colleagues. They are held in very high regard, they have enormous credibility in this neighborhood. Both districts are fortunate to be represented by two men of such extraordinary caliber and qualities of leadership.

So David, if you will—

Mr. PRICE. Shall we get opening statements first?

Mr. SCHEUER. All right, why do we not hear opening statements first and then I will ask Congressman Price to take the chair.

So Congressman David Price, your opening statement.

Mr. PRICE. Thank you, Mr. Chairman. I am grateful for your willingness to bring the Natural Resources Subcommittee to North Carolina, and for the fine work that the Subcommittee staff, Curt Stanford, Marty Ralston, have done in organizing this hearing.

In scheduling this hearing on the National Weather Service's performance here on November 28, and the capacity of the Weather Service to provide warnings of such disasters nationwide, you are dealing with policy questions of great concern in North Carolina and also of national significance. This hearing is typical of the responsiveness and leadership that you have brought to this Subcommittee and we are grateful to you.

I also want to thank my North Carolina colleague, Tim Valentine, for being here today. Congressman Valentine has recently been elected Chairman of the Science, Space, and Technology Subcommittee on Transportation, Aviation and Materials and we look forward to his leadership in this new position. Fortunately, Congressman Valentine will also continue to serve on the Natural Resources Subcommittee and we appreciate his help in bringing this hearing about today.

I also want to thank the teachers and the principal, Carolyn Earp of the Lynn Road school. As many of you know, this school is located very near to where the tornado touched down at several points. Many of the students in this school, families in this school were touched by the disaster. One student of this school was killed in the tornado. And so I think it is entirely fitting that we have this hearing today in the Lynn Road school and in this neighborhood, and we are very, very appreciative of the cooperation of Dr. Earp and of the staff of the school in helping us stage this hearing.

On November 28, a tornado tore through nine North Carolina counties, killing four people, injuring 157 others and damaging hundreds of homes and businesses. Wake, Franklin and Nash Counties were especially hard hit. Federal officials estimate that at least $77 million in damage was caused, including $61 million in Wake County.

The radar system at the National Weather Service forecast office at Raleigh-Durham Airport was inoperative at the time of this disaster. We have disturbing evidence that this failure is indicative of deeper problems at the Weather Service. The agency's budget is stretched to the limit. As a result, they are suffering from serious personnel shortages, a lack of available parts and outdated and obsolete technology.

Today, the Subcommittee is releasing the National Disaster Survey Report on the November 28 tornado. Commissioned by the National Oceanic and Atmospheric Administration, this study was conducted by a survey team of three National Weather Service personnel after the disaster. And I think I speak for all of us on the Subcommittee in saying that the findings of this survey team are most disturbing.

While the Raleigh forecast office staff performed as well as they could have, given the available resources, they were hamstrung by shortages in funding for personnel, outdated technology and missing parts. The Raleigh-Durham radar equipment was out of commission from November 20 to November 29 due to a lack of spare parts and the need for modification kits to make new parts fit old equipment. We need to know why it took so long for the Raleigh forecast office to receive that replacement part. Why was the part sent without the needed modification kit and, more importantly, why were there no qualified personnel available at the National Weather Service headquarters to advise and guide the Raleigh forecast office?

The survey team's report further documents the failure of backup systems. The Hatteras radar failed at critical times during this storm and the report describes power outages at Hatteras as "routine, sometimes occurring several times a day even in fair weather."

The Wilmington and Volens, Virginia systems issued no warnings at all about this storm. Particularly in Wilmington, staff shortages seem to have contributed to this failing. That too is documented in this survey team report.

In the end, however, it is not clear how adequate a warning could have been given even if all existing systems had been working perfectly. This raises the critical question of what state of the art equipment is available and what it is going to take to get that equipment installed at key stations like Raleigh-Durham.

The next generation Doppler radar, called NEXRAD, is currently under development. According to the report, with the Doppler detection capabilities found in the NEXRAD system, "An advisory watch or warning probably could have been generated before the storm struck the ground." Unfortunately the Raleigh-Durham weather station is not scheduled to receive this equipment until December of 1992.

We hope to accomplish several things today. We will look at the extent of destruction and the loss of lives and assess the performance of the National Weather Service in forecasting and warning. We will also identify new technologies and procedures to improve forecasting and warning systems, and we will examine the need for better coordination and cooperation between local, state and federal officials and the media during hazardous weather.

We also hope to help develop a legislative agenda for this Subcommittee in the upcoming reauthorization hearings for the National Weather Service.

This disaster of course is most present and most real to the neighborhood and the counties in which we are holding this hearing, and this process of recovery, this process of bouncing back is still very much going on.

But what we are dealing with here in this evidence about National Weather Service capabilities—what we are dealing with is a problem of national significance, a problem that we are going to have to deal with as we look at the authorization for the National Weather Service over the next several years.

So this is a hearing that has both local and national implications. We are very, very grateful for Chairman Scheuer's leadership in bringing this hearing to our area.

We are also fortunate in having some excellent witnesses here today to help us address these questions. I thank them all for coming and look forward to hearing their testimony.

Mr. SCHEUER. Thank you very much, Congressman Price. Now we will hear from the Chairman of the Transportation and Materials Subcommittee, Chairman Tim Valentine.

Mr. VALENTINE. Thank you very much, Mr. Chairman.

I do not know whether I have got this microphone close enough or not, but I certainly do not want anybody to miss any of my pearls of wisdom, so I will get it in here closer.

[Laughter.]

Mr. VALENTINE. I want to take this opportunity to thank Chairman Jim Scheuer for another appearance in the Research Triangle Park—Research Triangle area. He is here today, as has been stated, in David's district in which we also have many interests. He has been here in the past, as he stated, in fact in 1984 down in the eastern end of our district, in Rocky Mount, to hold a hearing on a similar subject. So he is well known to us here and is familiar with this part of the world and some of our problems.

I want to also express my appreciation for the contribution which has been made by David Price in the time that he has been in Congress. He is an outstanding member of the House of Representatives and I think that all of us are fortunate that he is a part of the representation which the State of North Carolina sends to that institution.

On a personal note, I am going to ask that my prepared opening statement be placed in the record and I will not trespass on your time and patience to read all of it. I do want to draw to the attention of my colleagues and the witnesses and those who are here to a part of it, but before I get to that I want to say a personal word or two. That it is a special treat for me to be here in a part of the school system in this county inasmuch as my only daughter and youngest child is one of David Price's constituents and supporters and is a new teacher in this system. And as fate would have it, I learned of this tragedy from Beth. She was married on the Saturday before this tornado struck and called me from Aspen, Colorado where she had seen on national news the tragedy which had occurred. So I was awakened early that morning with the news in that fashion.

We want to have not just an exercise here today, but we want to have an opportunity to get information from these witnesses which will help us to make a record which will enable us—by us I mean Chairman Scheuer and others on the Subcommittee and full Committee and our colleagues in Congress—to get sufficient attention to address this real, really acute problem.

Although the hearing this morning is being conducted under the auspices of the Natural Resources Subcommittee, the Subcommittee which I have the privilege of chairing—and I want to say here parenthetically that the fact that I am now the Chairman of a Subcommittee in the Congress is in my opinion the seniority system at its very best.

[Laughter.]

Mr. Scheuer. Well you know, Tim, when I first came to Congress, I was a reformer in those days and I was against the seniority system. I thought we ought to pick the best man regardless of seniority. But as I accrued age and experience and wisdom and seasoning—

Mr. Valentine. —and seniority.

Mr. Scheuer. —seniority began to look better and better—

[Laughter.]

Mr. Scheuer. —with every passing year. So I salute you. This is one of the outstanding successes of the seniority system and a joinder with true talent.

Mr. Valentine. Thank you, sir. By George, I did not realize it would elicit a further statement from you, for which I am grateful.

Mr. Scheuer. As a matter of fact, I remember advising Tim Valentine when he first came to Congress, I said, "Tim, now do not have an inferiority complex. I know for the first six months you wonder how you ever got here but right after that you will begin to wonder how the rest of those characters ever got here."

[Laughter.]

Mr. Valentine. I wanted to point out simply in a few—thank you, Mr. Chairman—in a few sentences from my prepared text, to mention the fact that some jurisdiction in the overall ability in the development of a new weather observation system is within the responsibility of our Subcommittee, the TAM Subcommittee, Transportation, Aviation and Materials. More specifically, the NEXRAD system. And as Chairman of the TAM Subcommittee, I intend to pursue this matter to the fullest extent possible, especially since the weather forecasting responsibilities are shared among the Federal Aviation Administration, the Air Force and the National Weather Service.

Incidentally, according to the National Weather Service, the NEXRAD radar is scheduled to be in place at Raleigh-Durham International Airport in December 1992.

And I ask, Mr. Chairman, that the rest of my prepared statement be inserted in the record, and thank you, sir.

Mr. SCHEUER. There being no objection, so ordered.

[The prepared statement of Mr. Valentine follows:]

THE HONORABLE TIM VALENTINE
SUBCOMMITTEE ON NATURAL RESOURCES,
AGRICULTURE RESEARCH AND ENVIRONMENT
LYNN ROAD ELEMENTARY SCHOOL
RALEIGH, NORTH CAROLINA

MARCH 3, 1989

## TORNADO FORECASTING AND SEVERE STORM WARNING

MR. CHAIRMAN, I WOULD LIKE TO ADD MY THANKS TO YOU FOR TAKING TIME OUT OF YOUR BUSY SCHEDULE TO COME AND HOLD THIS HEARING. THE CITIZENS OF BOTH THE SECOND AND FOURTH DISTRICTS ARE GRATEFUL TO YOU AND THE FULL COMMITTEE CHAIRMAN, MR. ROBERT ROE, FOR YOUR WILLINGNESS TO HOLD THIS HEARING ON THE TORNADO THAT ROARED THROUGH RALEIGH AND OTHER PARTS OF THE SURROUNDING AREAS JUST AFTER THANKSGIVING.

I ALSO WANT TO THANK THE FACULTY AND STAFF OF LYNN ROAD ELEMENTARY SCHOOL FOR THEIR COOPERATION AND ASSISTANCE IN LETTING THE SUBCOMMITTEE USE THE AUDITORIUM.

TWO PERSONS WERE KILLED IN RALEIGH AND TWO MORE IN NASH COUNTY, WHICH IS IN MY CONGRESSIONAL DISTRICT. AMID THE DESTRUCTION AND DEVASTATION, 982 FAMILIES WERE LEFT HOMELESS AND 157 INJURED, 200 BUSINESSES, INCLUDING A K-MART SHOPPING COMPLEX, WERE DESTROYED, ALL AMOUNTING TO MORE THAN $77 MILLION IN DAMAGES.

DESPITE THE DEVASTATION CAUSED BY THE TORNADOS, WE CAN LOOK BACK ON THE DISASTER WITH AT LEAST A SMALL DEGREE OF RELIEF AND COMFORT. WITH THE INTENSITY AND SPEED OF THE STORM, IMAGINE WHAT THE CONSEQUENCES COULD HAVE BEEN HAD TORNADOS OF THIS STRENGTH STRUCK DURING THE BUSY HOURS OF THE DAY. NONETHELESS, THE TORNADOS CAUSED MANY PERSONAL TRAGEDIES, AND THE PAIN AND FEAR OF THAT NIGHT WILL BE WITH THE PEOPLE FOR A LONG TIME.

IN MARCH 1984, TORNADOS ROARED THROUGH MUCH OF NORTH AND SOUTH CAROLINA, CAUSING MORE THAN $200 MILLION IN DAMAGES, LEAVING 59 PERSONS DEAD, ABOUT 1300 INJURED, AND MORE THAN 3000 PEOPLE HOMELESS. THE EFFECTS OF THESE KILLER TORNADOS, JUST LIKE THE ONES THAT HIT RALEIGH, LINGER IN THE MINDS OF THE PEOPLE DIRECTLY AFFECTED BY THIS TRAGEDY.

THE HEARING THIS MORNING WILL ALLOW US TO EXAMINE AND REVIEW FURTHER THE DESTRUCTION AND LOSS OF LIFE IN THE WAKE OF THE NOVEMBER TORNADOS. I AM PARTICULARLY PLEASED THAT WE WILL HEAR ABOUT THE PERFORMANCE OF THE NATIONAL WEATHER SERVICE IN ISSUING SEVERE WEATHER WARNINGS. ACCORDING TO SOME NEWS REPORTS, WARNINGS HAD NOT BEEN ISSUED AT THE TIME THE TORNADOS STRUCK RALEIGH. THE WEATHER SERVICE AT THE LOCAL AIRPORT, ACCORDING TO THESE SAME REPORTS, INDICATED THAT, "A TORNADO LIKE THIS....WHICH OCCURRED AT NIGHT, SUDDENLY INTENSIFYING, AND WITH HIGH SPEED....IT IS JUST VERY DIFFICULT TO GIVE ANY KIND OF WARNING."

AIRPORT METEOROLOGISTS ALSO REPORT THAT THE WEATHER RADAR WAS INSUFFICIENT TO DETECT THE STORM CELLS THAT SPAWNED THE TORNADOS. GROUND INTERFERENCE PREVENTED THE CURRENT AIRPORT RADAR FROM DETECTING THE STORM CELLS. THIS CLEARLY ILLUSTRATES THE NEED FOR THE DEVELOPMENT AND DEPLOYMENT OF WEATHER TECHNOLOGY SUFFICIENT TO DETECT AND PREDICT SEVERE STORM BEHAVIOR.

AS A MEMBER OF THE SUBCOMMITTEE, I WANT TO GAIN A BETTER UNDERSTANDING OF THE PERFORMANCE OF THE NATIONAL WEATHER SERVICE ON THE NIGHT OF THE TORNADOS. I UNDERSTAND THAT THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, WHICH HAS JURISDICTION OVER THE SERVICE, HAS COMPLETED AN EVALUATION OF THE PERFORMANCE BUT HAS YET TO RELEASE THOSE FINDINGS. THE NOAA REPORT APPARENTLY FINDS THAT THE NATIONAL WEATHER SERVICE OFFICES IN NORTH CAROLINA DID NOT PROVIDE ADVANCE WARNINGS TO THE PUBLIC. FURTHER, NO WATCH WAS ISSUED AS THE LOCAL RADAR EQUIPMENT WAS OUT OF SERVICE AT THE RALEIGH FORECAST OFFICE.

THE REPORT ALSO INDICATED THAT STAFF WAS NOT SUFFICIENT TO HANDLE THE RAPID, SIGNIFICANT INCREASES IN WORKLOAD ONCE DAMAGE REPORTS AND OBSERVATIONS OF SEVERE WEATHER BEGAN TO BE RECEIVED. OTHER FACTORS ALSO PLAYED A SIGNIFICANT PART IN DELAYING WEATHER WARNINGS TO THE PUBLIC. THESE INCLUDED LIMITATIONS IN COMMUNICATIONS EQUIPMENT AND DEFICIENCIES IN OPERATIONAL PROCEDURES USED BY THE NATIONAL WEATHER SERVICE AND THE MEDIA.

AS I THINK BACK ON THE NOVEMBER TORNADOS AND THE INHERENT PROBLEMS ASSOCIATED WITH PROVIDING ADVANCED PUBLIC NOTICE, I CANNOT HELP BUT RECALL A HOST OF PROBLEMS THAT PLAGUED EFFECTIVE WEATHER REPORTING DURING THE 1984 TORNADOS. THERE ARE MANY SIMILARITIES IN THE TWO REPORTS THAT WARRANT FURTHER DISCUSSIONS.

ALTHOUGH THE HEARING THIS MORNING IS BEING CONDUCTED UNDER THE AUSPICES OF THE NATURAL RESOURCES SUBCOMMITTEE, THE SUBCOMMITTEE I NOW CHAIR, THE SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS, ALSO HAS SOME JURISDICTION IN THE OVERALL ABILITY IN THE DEVELOPMENT OF NEW WEATHER OBSERVATIONAL SYSTEMS, INCLUDING NEXRED. AS CHAIRMAN OF THE TAM SUBCOMMITTEE, I FULLY INTEND TO PURSUE THIS MATTER TO FULLEST EXTENT POSSIBLE, ESPECIALLY SINCE WEATHER FORECASTING RESPONSIBILITIES ARE SHARED AMONG THE FEDERAL AVIATION ADMINISTRATION, THE AIR FORCE, AND THE NATIONAL WEATHER SERVICE. INCIDENTALLY, ACCORDING TO THE NATIONAL WEATHER SERVICE, THE NEXRED RADAR IS SCHEDULED TO BE IN PLACE AT THE RALEIGH-DURHAM INTERNATIONAL AIRPORT IN DECEMBER 1992.

FINALLY, I BELIEVE THAT DETECTION OF TORNADOES AND SEVERE STORM PREPAREDNESS DEPENDS ON A WELL-COORDINATED LOCAL EMERGENCY NETWORK. TO ENSURE ADEQUATE EMERGENCY RESPONSE IN ANY DISASTER, IT IS NECESSARY TO HAVE IN PLACE PEOPLE AND EQUIPMENT TO DEAL WITH SUCH EMERGENCIES. WHILE I DO NOT KNOW ALL THE DETAILS OF THE NOVEMBER TORNADO, I BELIEVE THAT THIS AREA COULD HAVE BEEN BETTER SERVED IN THE AFTERMATH OF THE DESTRUCTION.

I LOOK FORWARD TO HEARING ANY SPECIFIC RECOMMENDATIONS FROM OUR PANELISTS TO IMPROVE WEATHER REPORTING AT THE AIRPORT. I HOPE THESE PROPOSALS WILL INCLUDE RECOMMENDATIONS FOR BETTER RADAR, ADEQUATELY TRAINED PERSONNEL, AND OTHER MEASURES TO ENSURE PUBLIC SAFETY DURING SEVERE STORMS AND TORNADOS.

Mr. SCHEUER. Now at this point, I am going to ask Congressman David Price to take over the chairing of this hearing. I am doing it for several reasons. First, because he is a very hard-working and contributing member of the Subcommittee, so he knows the general jurisdiction very, very well. And second, he has been on the ground, in the trenches, since the closing days of November of last year when this awesome tragedy hit this community, and has been living with it for 24 hours a day. So he has the knowledge of the subject matter which no Congressman living in New York, even chairing the Subcommittee, could ever have, because he not only knows the legality, he not only knows the problems of technology and so forth, but he has been living in this community trying to ameliorate the damage, talking to many of you, talking to the experts, absorbing their insights and so forth over a period of several months. He has been really up to his neck in it. And that will show in the way that he and Tim both lend their insights, their high intellectual brain power, their understanding and their compassion to producing answers that work.

So David, I would like to ask you to take over the gavel here.

Mr. PRICE. Thank you, Mr. Chairman.

We do want to move ahead with our panels. We have four outstanding panels of witnesses that can give us a perspective on this from their respective angles. We do have limited time, we are going to need to adjourn this hearing not too far past noon, and so we do need to move along, and we will try to expedite the proceedings in any way we can.

Our first panel is a group of distinguished local officials; Mayor Avery Upchurch of the City of Raleigh, Mayor Brenda Moody of the Town of Rolesville in the path of the tornado in northeastern Wake County, and Raymond Boutwell, the County Manager in Franklin County, a county to the northeast of Wake which was also in the path of the tornado.

So if those three witnesses will take their places, we will proceed. Let me just say to you and to the witnesses in general that we will be happy to put your prepared statement in the record. We would ask that you speak from that statement, but you do not necessarily need to read the entire statement. It would be fine for you to summarize, so we can move along and get on to the questions. So if you could try to limit your oral remarks to five minutes, we have the capacity to put the entire statement in the record and any other attachments that you would want to place with it

Mayor Upchurch, welcome, we will start with you.

## STATEMENTS OF AVERY C. UPCHURCH, MAYOR, CITY OF RALEIGH, NORTH CAROLINA; BRENDA MOODY, MAYOR, TOWN OF ROLESVILLE, NORTH CAROLINA AND RAYMOND BOUTWELL, COUNTY MANAGER, FRANKLIN COUNTY, NORTH CAROLINA

Mr. UPCHURCH. Thank you very much, Congressman Price, Congressman Scheuer and Congressman Valentine. Thank you for coming and allowing us this opportunity.

On November 28, 1988, at about 1:08 a.m., a tornado or the first of a series of tornadoes hit Raleigh. To digress and give you a personal observation, I lived within less than one-half mile of the first major area that was struck, that was the Town Ridge Shopping Center. I, every evening, with my dog take a walk at 10:30 to check the weather, literally, to see how things look for the next day. As we went out that night, there was no question in my mind there were storms brewing in our area. I went back into the house, it was very uncomfortable, we turned on ceiling fans. As the night progressed, about two to three minutes before the storm hit, my small dog, about 25 pounds, a water collie, knocked through a folding door at a force that I had never heard before and did not understand what was happening. Then approximately two minutes after that, the lights went out and there was total darkness. And then I experienced a few minutes after that a sound such as a jet noise and then total silence. Fifteen minutes later, there was the sound of sirens. The City Manager soon called me and I was on the scene at four a.m. and remained on the scene the rest of that day.

The tornado tore a path of ten miles long through northwest Raleigh, through the most densely populated area of the city. There are 1,174 residences which were either destroyed or received major damage. There were 49 businesses which were either destroyed or received major damage. In all, 2,254 residences and 66 businesses were damaged by the tornado. Two lives were lost.

The property owners in the area and the City are still cleaning up tornado debris. Through the end of February, the City has disposed of 34.5 million pounds or 17,200 tons of debris. The City estimates the cost of the tornado to be approximately $1.2 million and another loss of another half million dollars in property taxes.

The City of Raleigh had 1,100 employees working on tornado recovery for the first 24 hours after the storm. There were many other local agencies who helped with the recovery effort including the county Sheriff's Department, Emergency Medical Service, Emergency Management, many volunteer fire departments and rescue squads. There were 16 other cities in North Carolina that came to our rescue without even being notified.

The role of the state and federal government in helping with recovery was not clear. There was an enormous amount of time devoted to documenting costs and efforts in response to directions by federal officials. The results of that effort was no financial assistance to the city and additional work to the city staff at a time when it was a major burden. We had difficulty finding out what type of assistance had been approved by the federal government.

Raleigh staff did everything they could to cooperate with the state and federal government. In fact, on the morning of November 29, 1988, city staff adjourned a meeting that city and county staff was holding to answer and meet with the Federal Emergency Management officials who appeared at the municipal building. The meeting began with this body of officials announced that the name of the game with federal emergency dollars was "let's make a deal". We obviously lost the game.

There was no warning issued by the National Weather Service for this tornado. My understanding is that the radar at RDU was down for maintenance. I also understand that the type of radar in service at RDU is of 1957 vintage and among other things it cannot detect storms over that immediate area. I understand that the next generation of radar that will probably meet this need is 1992-1993.

This tornado did a great deal of damage and took two precious lives. The only thing that I feel that we did have working correctly was that our City Manager, Mr. Dempsey Benton, one year prior to this storm had developed a plan for such a disaster. His foresight is probably what saved many other lives and a great deal of property by having people on the site so quick and to their aid.

Thank you very much.

[The prepared statement of Mr. Upchurch follows:]

March 3, 1989

Mayor Avery C. Upchurch, City of Raleigh
Testimony before U. S. House Subcommittee on Natural Resources, Agriculture Research and Environment

## Impact of Tornado

On Novermber 28, 1988 at about 1:08 a.m., a tornado or the first of series of tornadoes hit Raleigh. The tornado tore a path 10 miles long through northwest Raleigh through the most densely populated area of the City. There were 1,174 residences which were either destroyed or received major damage. There were 49 businesses which were either destroyed or received major damage. In all 2,254 residences and 66 businesses were damaged by the tornado.

Two Raleigh citizens lost their lives in the tornado. One hundred five people sustained injuries serious enough to be taken to a hospital.

The property owners in the area and the City are still cleaning up tornado debris. Through the end of February, the City has disposed of 34.5 million pounds or 17,200 tons of debris. The City estimates its cost for tornado recovery to be approximately $1.2 million. The City will lose another half-million dollars annually in property taxes.

## Cooperation of Local, State, and Federal Officials

The City of Raleigh had 1,100 employees working on tornado recovery in the first 24 hours after the storm. There were many other local agencies who helped with the recovery effort including the County Sheriff's Department, Emergency Medical Service, Emergency Management, many volunteer fire departments and rescue squads. There were also 16 other cities in North Carolina which sent crews to help. These local agencies know how to help and the cooperation with City departments was excellent. In some cases, the help came without being requested.

The role of the State and Federal government in helping with recovery was not clear. There was an enormous amount of time devoted to documenting costs and effort in response to directions by Federal officials. The result of that effort was no financial assistance to the City and additional work to City staff at a time when it was a major burden. We had difficulty finding out what type of assistance had been approved by the Federal government.

Raleigh staff did everything they could to cooperate with State and Federal officials. In fact, on the morning of November 29, 1988, City staff adjourned a meeting of City and County staff who were coordinating recovery efforts to meet with Federal Emergency Management officials who appeared at the municipal building. The meeting began with the FEMA official announcing that the name of game with Federal emergency dollars was "let's make a deal." We obviously lost the game.

## Effectiveness of National Weather Service Warning System

There was no warning issued by the National Weather Service for this tornado. My understanding is that the radar at RDU was down for maintenance. I also understand that the type of radar inservice at RDU is of 1957 vintage and among other things can not detect a storm over that immediate area. I understand that the next generation of radar (NEXRAD) is not scheduled to be installed at RDU until 1992-93 which would significantly enhance the National Weather Service's ability to forecast tornadoes and to issue warnings.

In this tornado two precious lives were lost but many were spared. This tornado struck at a very unusual time, but it was a time when very few people were out and about. If there is a next time, the ability to have a warning will surely save lives.

Mr. PRICE. Thank you, Mr. Mayor.

Ms. Moody.

Ms. MOODY. Thank you, Congressman Price and Committee.

I also live within about a fourth of a mile from where the tornado struck and I was up at 1:30 that morning. My lights flickered and went off but I never heard a noise or any type of warning from the news media at all.

Through Wake County Building Inspections and real estate staff our area was assessed and surveyed and found 65 homes were damaged in our area; four were single family homes and four mobile homes were completely destroyed in this area.

The homes that are listed above in my report are located east of Neuse River between Rolesville and Wake Forest. The area most seriously affected is near the intersection of Forestville Road and Burlington Mill Road, which is better known as Walkers Crossroads. The other damaged homes lie in an arc extending southwest and northeast from that intersection, generally from Ligon Mill Road south of Wake Forest to the Franklin County line, which is northeast of Rolesville.

Volunteer fire departments, rescue squads, neighbors, friends and even strangers worked for days to help people salvage what could be salvaged, clean up debris, find temporary housing, cover homes that needed repair to avoid further damage, and to take care of the immediate needs of these people which were families, which was food, clothes, houses, et cetera.

The Red Cross finally came to our area late Monday afternoon and they were very surprised at the amount of damage that was in our area. I only have to guess at this, but I am wondering if it was because of the lack of regional and national media coverage, that said Raleigh was the damage that was in Wake County, and not further out. These people, the 65 homes that were damaged, bordered the area that was in the Raleigh area. Even the school system that day said that all electricity had been restored to the schools and so therefore school went on as normal but the schools in our area had no electricity at all that day. They did not get any hot meals, they did not have any heat in the buildings, no lights, but they were still required to be at school.

Raleigh Baptist Association was another agency that helped in our area before the federal government finally got agencies out there.

Being the proud people that we are, sometimes we do not always take advantage of what is offered to us, and especially if you have to stand in a line and have to answer the same questions over and over again and then you have to travel out of your community.

What I am getting at is that I think and feel that a system needs to be set up to where each municipality is given, over phone, bulletins or whatever, ways that are available for people to handle these emergencies. I think we need to make it easier for these people. Sometimes a warning system is not always effective. Of course there was people sleeping, the majority of the people were sleeping. Could they have heard a warning—if it had been working, could they have heard it? I know that our fire alarm, when it goes off, you can hear it for a four to five mile radius but sometimes when I'm sleeping, and I live less than half a mile from it, I cannot hear it. Even if these people could have heard this warning, would it not have caused mass confusion, would they have known what to do? With the warning going off and they not hearing it before, how would they have reacted? Would it have caused people to be out and be struck by debris that was flying, that could have been avoided?

We, through working to get this information together, some type of bulletin, like I said before, that could come over the phone to help us know what is available immediately would have been a help to these people. If it had not been for our volunteers in that area, I would not have been able to know what to do. The people that needed help would have not known what to do, and even so, before some of these people got help, they went to other areas of the county and after the news media finally said there was damage in the Rolesville area and came out that way, I could not locate some of the people, they had already gone.

There is debris still laying around now, homes that were demolished that have not been touched. Let us work together, all of us, in trying to make it easier for these people to know what to do when a tragedy happens like this. We are not always able to advise them in advance, but let us try to make it easier for them after the devastation has taken place.

Thank you.

[The prepared statement, plus attachments of Ms. Moody follow:]

# Town of Rolesville

**POST OFFICE BOX 250 ROLESVILLE, N.C. 27571**
**PHONE 919/556-3506**

February 28, 1989

James H. Scheuer, Chairman
Subcommittee on Natural Resources,
Agriculture Research and Environment
Washington, D. C. 20515

Dear Mr. Scheuer:

While sleeping safely in my bed on November 28, 1988 approximately a fourth of a mile away friends and neighbors were being rudely awakened by winds that sounded like a train coming, trees snapping and crashing through roofs and windows, debris flying and their homes being demolished and some even disintegrating before them. Three months later people are still trying to recover from the devastation.

A woman sleeping on a couch reportedly heard the wind and grabbed the couch and rode it approximately 200 yards. Alone, frightened and in the dark, she finally made it to the neighbors home, some 400 to 500 yards away and awakened them for help.

Another couple and their son were wakened by a tree crashing through a window and later realized the roof on their brick home was gone.

Flying wood and glass woke another couple as it made its way into their bedroom near Rolesville and they discovered their backyard scattered with debris from four barns and a new Blazer that had been overturned and then uprighted.

Yet another woman lying in bed heard a noise then found herself still lying with her head on her pillow but the bed mattress was on top of her and she was on the ground.

Another area resident was critically injured when his mobile home was lifted into the air and crashed to the ground on the opposite side of the road. To date he is still in the hospital in critical condition while his family waits patiently not knowing what tomorrow will bring. Can you imagine the devastation of losing everything you own, not just the material things that can be replaced or the personal items that do not have a cash value, but to also be faced with a loved one, a father, a husband living on the rim of life and death for 3 months? Could this family have possibly been spared this turmoil and devastation if they had been warned?

These are just a few of the families that were touched by the disaster of a tornado on that morning of November 28, 1988, while others were safe and sound in their homes not knowing what was happening to their friends and neighbors. They had listened to the weather report before bed. No warning came. They slept peacefully. No warning came. People were injured and in need of help. No warning came.

Wake County Building Inspections and Real Estate staff surveyed and assessed the level of damage outside the Raleigh City limits. A total of 65 homes were affedted by the storm. The number of homes that were completely destroyed was 8 and 5 had major damage. The following residential damage was identified:

| | Uninhabitable | | | | Affected/ Habitable | Total |
|---|---|---|---|---|---|---|
| Type of Home | Destroyed | Major Damage | Minor Damage | Inaccessible/ or No Util. | | |
| Single Family | 4 | 3 | 14 | 1 | 18 | 40 |
| Mobile Home | 4 | 2 | 6 | 0 | 1 | 13 |
| Multi-Family | 0 | 0 | 6 | 0 | 6 | 12 |
| Totals | 8 | 5 | 26 | 1 | 25 | 65 |

The homes listed above are located east of the Neuse River, between Rolesville and Wake Forest. The area most seriously affected is near the intersection of Forestville Road (SR 2049) and Burlington Mill Road (SR 2045). This area is better known as Walkers Crossroads. The other damaged homes lie in an arc extending southwest and northeast from that intersection, generally from Ligon Mill Road (SR 2044) south of Wake Forest, to the Franklin County line, northeast of Rolesville.

Volunteer Fire Departments, Volunteer Rescue Squads, neighbors, friends and even strangers worked for days to help these people salvage what could be salvaged, clean up debris, find temporary housing, cover homes that needed repair to avoid further damage and took care of their immediate needs, i.e. food, clothes.

The Red Cross came to the Rolesville Volunteer Fire Department late Monday afternoon. They were very surprised at the amount of damage in the area. I wonder why it took them so long to come to our area. I can only guess, but was it due to the lack of coverage from the news media? As far as the regional and national news reported, Raleigh was the only part of Wake County that was involved in the destruction of the tornado. Even Wake County Schools said that electricity had been restored to the schools and the school day went on as usual. The only difference was that Rolesville students did not have electricity all day... no lights, no heat and no hot meals. Breakfast consisted of cereal and milk. For lunch they were feed cheese and a peanut butter and jelly sandwich, fruit and milk.

The Raleigh Baptist Association was one agency that offered help on Monday before the Red Cross arrived. Funds were used from the Volunteer Firemans Fund to help buy food to feed the volunteers and the families in need.

After the news media emphasized the destruction in our area, other agencies such as the Raleigh Home Builders Association started calling the town hall to offer help for immediate needs. This was on Wednesday. I was able to locate the property that received damage but the people had found other places to stay and we were unable to locate all of them.

Being the proud people that we are, sometimes we don't take advantage of all the help offered. Especially if we have to stand in lines, answer the same questions over and over and travel out of our own community.

We are all concerned about the effectiveness of a storm warning system in our area, but sometimes things just happen too fast for a warning to come in time. People were sleeping, the television and radio would have been useless to these people. An alarm warning possibly could help in each community but without proper training on what to do when certain warnings come and the continued communication with each community, there could be mass confusion. How effective will this be? Maybe it was fortunate that no warning was given since people who might have been outside their homes during the twister could have been struck by flying debris.

I think that we need to look at making it easier for people to handle the situation after devastation has happened. All people should be treated equally. I can understand not paying for damage that insurance would cover. Each person should have the opportunity to partake of Federal Funds whether it be by loan or grant. Why should an American that has worked hard and is capable of borrowing money not be given the opportunity to borrow low interest money? After all, it is money that he has paid through taxes! Why should only the citizens that have nothing be given that opportunity? Are we punishing the citizens that work hard to acquire a home and property by saying that you own too much.

One major concern is the coordination of helpful information for town, county, state and federal officials. The town officials - through the municipal governments should have immediately received from the state, federal and/or county agency a bulletin, over the phone, of help that was available and could be utilized immediately. Most larger municipalities have staff that can help with some of this coordination. I never received a notice of any available service for these victims. Through local resources and lots of neighborhood volunteers, life was a little easier for some of them. Helping these victims return to their normal life style as soon as and as easily as possible; whether it be in an apartment that has been rented or another home, should be a top priority. They are already in a stressful situation and helping them cope with the situation should be of upmost concern.

Although no damage was reported inside of the town limits of Rolesville, the community was affected. By keeping local officials aware of help that is available and the proper procedures for acquiring this help, is just one way of making life easier for victims that are already devastated.

The instinct to survive any situation, especially a disaster is far greater than any pain suffered when we endure it. Lets's all work harder at easing the pain.

On behalf of the Town of Rolesville, the community, myself, and the victims of circumstance, I would like to express our thanks for scheduling this hearing and taking the time to listen to our concerns.

Sincerely,

Brenda Moody

Brenda Moody
Mayor
Town of Rolesville

The following data was collected by the Wake County Tax Office. To help you evaluate the situation. I have compiled the following figures from their data. This data is also reflected on page 2 of my letter.

1. The total dollar loss is $438,235. This figure reflects an inflation of 10% to include personal possessions loss.

| | Estimated Income | | | |
|---|---|---|---|---|
| Type of Home | High | Medium | Low | Total Dollar Loss |
| Single Family | 0 | 23 | 17 | $ 317,677 |
| Mobile Homes | 0 | 2 | 11 | 88,110 |
| Multifamily | 0 | 0 | 12 | 32,448 |
| Total | 0 | 25 | 40 | $438,235 |

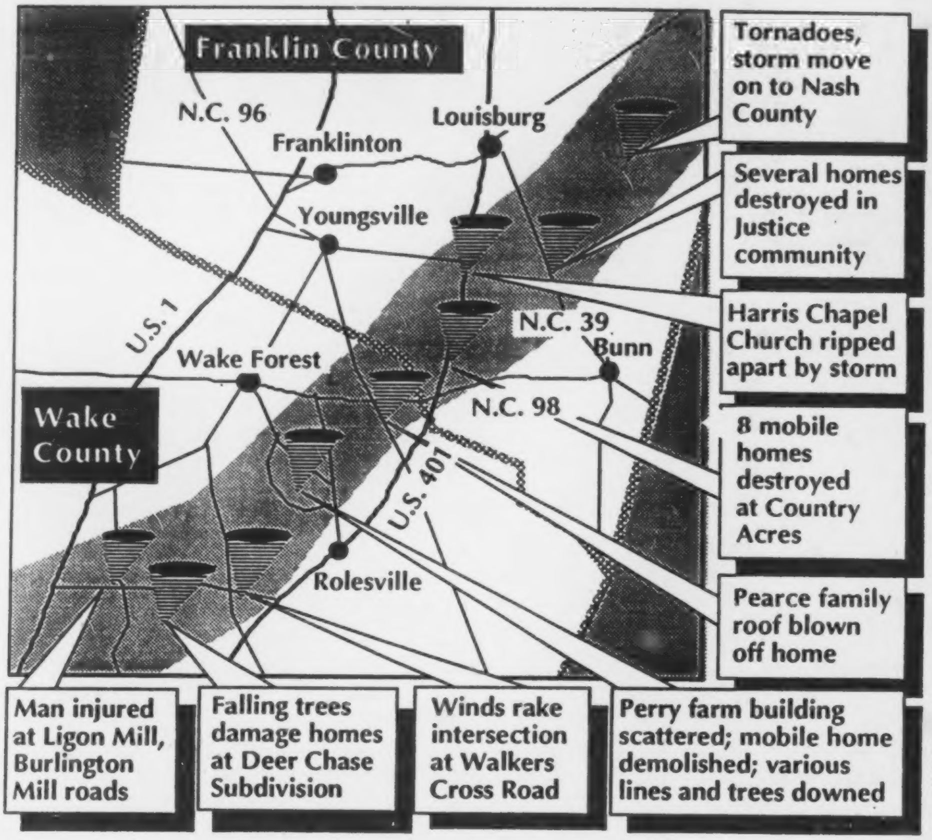
2. The income level of the families with completely destroyed homes or homes with major damage is:

| | Estimated Income | | | |
|---|---|---|---|---|
| Type of Damage | High | Medium | Low | Total Dollar Loss |
| Destroyed (8) | 0 | 1 | 7 | $ 163,004 |
| Major Damage (5) | 0 | 2 | 3 | 66,500 |
| Total (13) | 0 | 3 | 10 | $ 229,504 |

Please keep in mind that this report only reflects the residential property damage. The loss of barns, storage buildings, farm equipment, businesses etc. are not reflected in the dollar value nor the number of reported damages. The dollar value also does not include doctor and hospital charges for physical injury.

As of February 10, 1989, after the February 2, 1989 Disaster Field Office deadline, approximately 7 families had established application files at the Field Office. Wake County is currently compiling a complete list of those owning or renting the homes affected.

# Tornadoes rip path through counties


Franklin County
N.C. 96
Franklinton
Louisburg
Youngsville
U.S. 1
Wake Forest
N.C. 39
Bunn
N.C. 98
Wake County
U.S. 401
Rolesville

Tornadoes, storm move on to Nash County

Several homes destroyed in Justice community

Harris Chapel Church ripped apart by storm

8 mobile homes destroyed at Country Acres

Pearce family roof blown off home

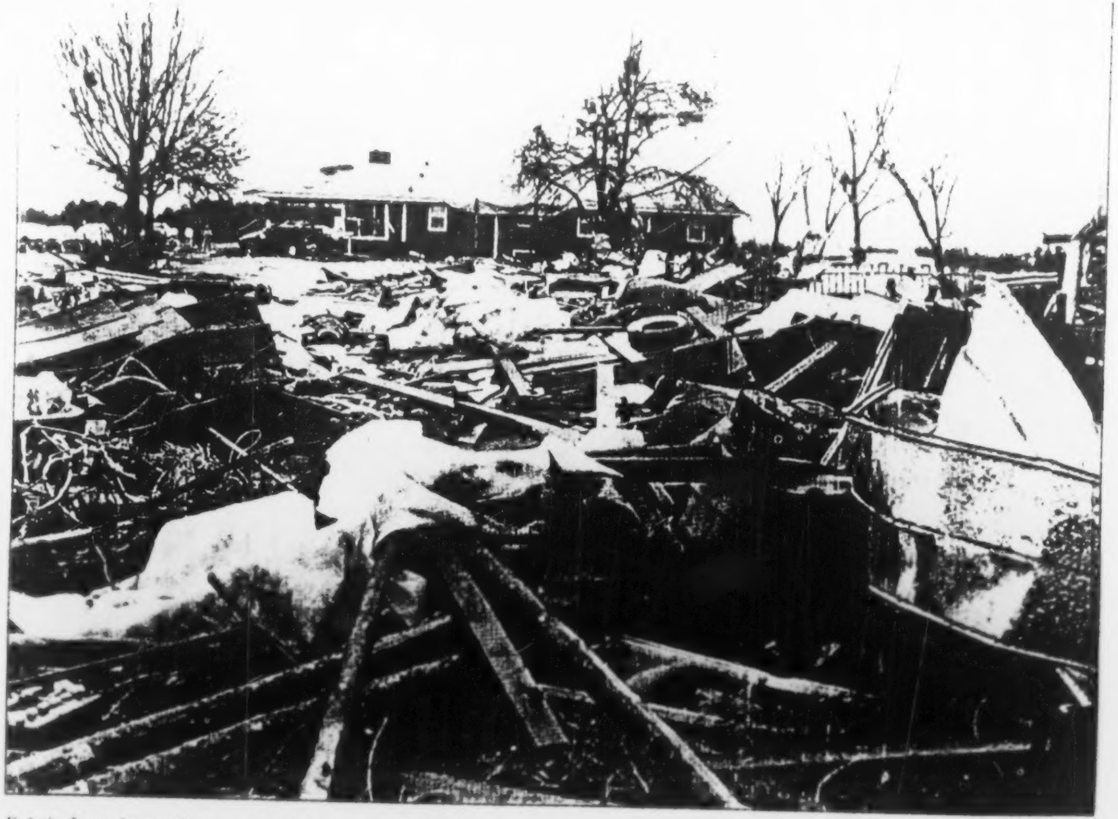
Man injured at Ligon Mill, Burlington Mill roads

Falling trees damage homes at Deer Chase Subdivision

Winds rake intersection at Walkers Cross Road

Perry farm building scattered; mobile home demolished; various lines and trees downed

*The storm hit northern Wake and Franklin Counties about 1:30 a.m. Monday and tornadoes blasted a pathway to the northeast, ripping through trees, homes, power lines and churches. This chart shows some, but not all, of the damage.*

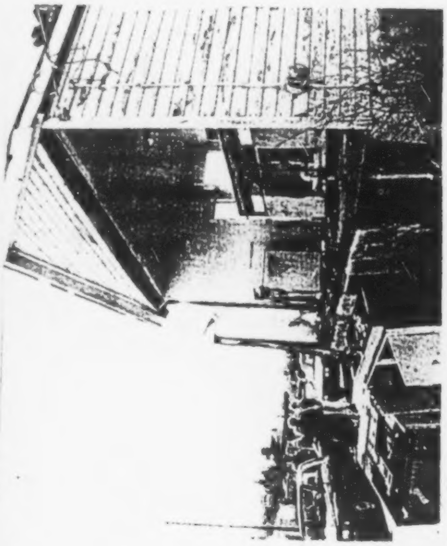


Debris from barns litters yard of house on SR 2053

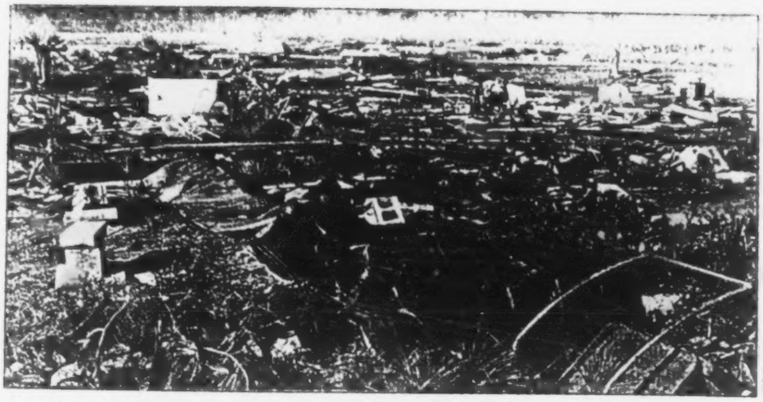
Tree crashed onto car in Deer Chase subdivision

Wake Weekly/DAVID COPELAND

Roof on family's house on N.C. 96 was blown away



Section of store at Walkers Crossroads was demolished



Remains of Williamson mobile home on SR 2054

ibors sort through Atkins belongings at SR 2044 and SR 2045

Wake Weekly/FRANK S

Mr. PRICE. Thank you, Mayor Moody, and we will include your full written statement and the attachments in the Committee record.

Mr. Boutwell, the County Manager of Franklin County.

Mr. BOUTWELL. Thank you, Congressman Price. First, let me just thank you for the opportunity to appear and describe what happened in Franklin County.

The tornado, it seems like we were going through its path as it started in Raleigh and it moved in a northeasterly direction. It hit Franklin County at the Wake-Franklin County line just above Rolesville and proceeded 22 miles northeasterly. Through the path of destruction it appeared to us that it was just one large tornado because it was pretty much along a straight line, 350 feet wide.

We had a number of homes destroyed and damaged as well as businesses and churches. I have some pictures attached to the statement for the record. I also have brought a videotape that I will leave with you for your opportunity to look at. It is footage of some of the destruction in Franklin County later on the day that it occurred.

Fortunately in Franklin County we had no fatalities. We did have 17 personal injuries. We estimate that we had over $11 million worth of damage.

To give you an idea what that means to Franklin County, that is the equivalency of about one and a half cents on our tax rate, and to us that is a great deal.

As far as in Franklin County, we relied very heavily on our local volunteers. If it had not been for our volunteer fire and rescue services, we would not have been able to respond to the needs of the people as well as to clearing the roads and that sort of thing.

Fortunately also, our communication system was not damaged during the tornadoes, we were able to at least broadcast over the police and fire network about the tornado, and some residents in the county heard this on their scanner. In fact there was one family who had the opportunity to hear this and the gentleman took his family and put them all in the basement and about five minutes after he did that, the tornado came through and took his house out from over their heads, but they were unharmed.

Mr. PRICE. Where did that information come from?

Mr. BOUTWELL. That information? From our police and fire rescue—he had a scanner. It was not on the weather channel, it was on the local police and fire—

Mr. PRICE. Do you have any idea how long before that, that information had been broadcast?

Mr. BOUTWELL. No, sir. In fact, when it first hit, I guess they estimated it was about a 15 to 20 minute span between the time it took to cut across the county, so it could not have been much notice there. There was no first—the first notice that we got was when it actually hit in Franklin County. So we did not hear of Wake County first before it hit us.

Mr. PRICE. I see.

Mr. BOUTWELL. As far as the effectiveness of the National Weather Service system, I think that your technical consultants can respond to that better than we can, although we do understand that because of the unusual circumstances around this storm, that it may have been difficult even if they had the proper equipment, it may have still been difficult for some early detection.

In summary, Franklin County is still undergoing some of the cleanup measures. We have had some people who have been displaced. We are continuing, as far as financial assistance, looking at other means because for the most part the financial assistance that was available through the disaster center has not been available for our victims. From what I can assess, the financial assistance received has, for the most part, been through unemployment and private donations which some of the people in Franklin County banded together.

[The prepared statement of Mr. Boutwell follows:]

## TESTIMONY OF RAYMOND G. BOUTWELL, FRANKLIN COUNTY MANAGER

Testimony Before The Committee on Science, Space, and Technology: Subcommittee on Natural Resources, Agriculture Research, and Environment U. S. House of Representatives

### Amount of Destruction

The tornados which struck Franklin County on November 28, 1988 first hit Franklin County at the Wake-Franklin County line in the southwest corner of Franklin County. The tornados continued a path of destruction in a northeasterly direction. The path was 22 miles long and 350 feet wide. The following is a listing of the damages:

27 homes totally destroyed (18 mobile homes)

12 homes with major damage (3 mobile homes)

10 homes with minor damage (2 mobile homes)

3 churches destroyed

1 church damaged

3 chicken farms damaged with 23 farm buildings

2,500 acres of farm land affected

300 acres of wheat damaged

100 acres of oats damaged

several pieces of farm equipment

30,000 chickens killed

extensive erosion

17 personal injuries ( no fatalities)

Franklin County was fortunate that the path of the tornados was in the rural areas of the county. Damage to property and life was kept to a minimum because of this. However, $11,000,000 worth of damage is devastating to a county of our size.

### Level of Coordination And Cooperation

Franklin County relied heavily upon the efforts of volunteers during and after the tornado disaster. Volunteer fire and rescue units worked throughout the morning and that day assisting the victims. Church groups and civic organizations rallied to provide financial and psychological assistance to the victims. Local cooperation was at a peak. In our assessment, local coordination could have been better.

The state division of emergency management provided prompt service in coordination and assistance. Representatives from that division arrived shortly after daybreak and toured the area of devastation. The federal emergency management agency, division of emergency management, and local emergency management personnel worked quickly to assess the damage. The comments I have heard from victims concerning the service provided have been for the most part positive. The biggest concern expressed is a feeling of frustration concerning not obtaining any financial assistance from these agencies.

### Effectiveness of the National Weather Service Warning System

We understand that there was a breakdown in the national weather services' severe storm warning system in the Raleigh-Durham area at the time of the tornados. From what I have heard from meteorologists and state agencies, this particular storm created an unusal set of circumstances for early detection. Since we do not have the expertise in evaluating such systems, it is important for us not to criticize.

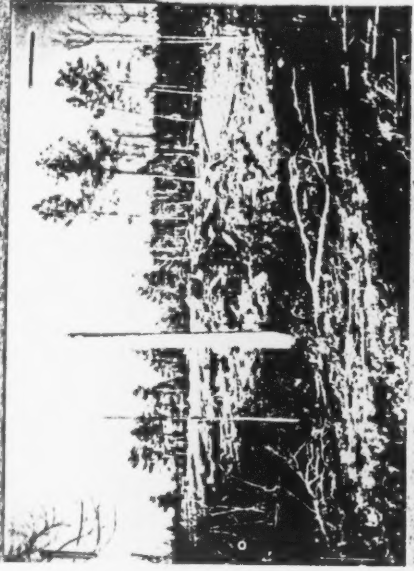
In general, since most people were asleep at the time of the tornados, any forewarning may have gone on deaf ears. Most people do not have scanners that they keep on at night to warn them. If technology is such that we know many hours in advance, then there may be room for criticism. The criticism that we have of the handling of the disaster episode is more on a local level. It appeared that we were not as organized as we would like to have been to respond. However, the volunteer organizations showed that they were prepared to respond.

Attached are pictures of the devastation throughout Franklin County.

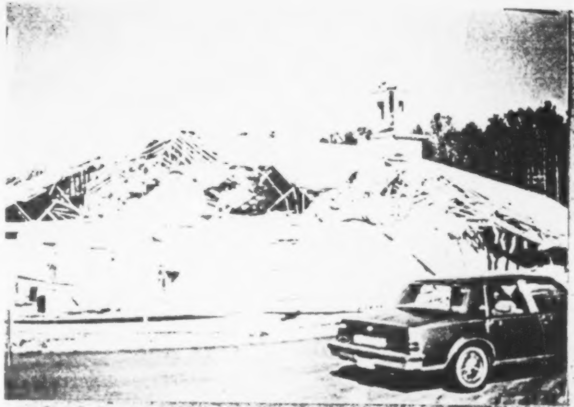
CHICKEN HOUSES - FRANKLIN COUNTY

CHICKEN HOUSES - FRANKLIN

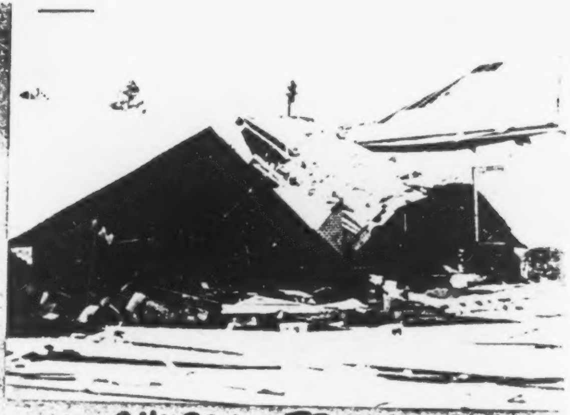
CHICKEN HOUSES - FRANKLIN COUNTY



MOBILE HOME PARK



CHURCH · FRANKLIN COUNTY



CHURCH · FRANKLIN COUNTY

WOODLAND · FRANKLIN COUNTY

WOODLAND · FRANKLIN COUNTY

Mr. **Price**. Thank you, Mr. Boutwell and thanks to all of our witnesses for some very helpful testimony.

If we might, I would like to bring your statements to focus on the main topic of this hearing, which is the timing of the warnings that your cities and towns and counties received or did not receive as this tornado came upon us. Could you comment specifically on the kind of warning that you had and also of any official or semi-official arrangements that you have to receive warnings and to disseminate information when a disaster like this arises? For example, do you make any use of the NOAA Weather Radio System? Do you monitor that or have dispatchers that do monitor that, or any other system that you have in place to take advantage of whatever information is out there?

Mayor Upchurch?

Mr. **Upchurch**. We have an emergency communication center in City Hall and it is the county/city facility, state-of-the-art, and we can immediately alert and be in contact with people or groups. But we had no warning of the storm, so there was nothing that we could send out. Our first knowledge was a phone call from a resident that lived on the edge of Upton Park, who called and said something had happened and it had blown the roof of their house off. So that is when we began to dispatch, but immediately it began to come in from other areas. The telephones were not knocked out because the telephones in that section of the city, many of them, are underground, so therefore the wires were not knocked down, but the power was out.

But we have the ability to communicate. But as to how we could at that time of night, because the radios are all turned off, everyone is in the bed, it would have been difficult to know where the tornado was going to strike—there are a lot of unanswered questions, but we do have a system that could actually make some effort to notify people.

Mr. **Price**. And is the NOAA system monitored, do you know? Is that done regularly?

Mr. **Upchurch**. I cannot say definitely because I am not the technical man and he is not with me. I am sure it is.

Mr. **Price**. But you are in a position to disseminate information when and if it is received, and in this case it was not received.

Mr. **Upchurch**. It was not received. We can certainly disseminate information.

Mr. **Price**. Ms. Moody or Mr. Boutwell, do either of you have anything to add?

Ms. **Moody**. The only thing that I can say is that we are connected in through Raleigh Channel 5 and after they had heard, they let our police officers know and the rescue and fire, but as far as being able to get it in advance to let the people know, we were not—we did not have any warning, and even if we had gotten the warning, the only thing that we have in our area to notify them would be the fire alarm, and if that went off, you know, they would just think it was a fire.

Mr. **Price**. As you said, that kind of warning could easily be misinterpreted and might in some cases even make the situation worse.

Mr. Boutwell?

Mr. **Boutwell.** Congressman Price, we do have at our communications system a monitor, whether it is exactly the NOAA system I am unaware at this time. One of the things that we have found as a result of the tornado disaster is that we need, on a local level, to reassess our ability to respond and to monitor these types of things.

Mr. **Price.** The main focus of the hearing today is on the Weather Service and the kind of warnings that ought to be available in advance of a disaster such as this. All of you, though, have also touched on other aspects of the disaster, and in particular, the kinds of assistance that have been available or unavailable, as the case might be.

Mayor Upchurch, you in particular I know, the City of Raleigh, have been frustrated in efforts to get assistance for debris removal, and I know those efforts, which we have helped with in every way we can, have been frustrated. It is true, and I think it is important to indicate for the record that it is true, that individuals have received considerable assistance. The federal officials and state officials worked together very well to reach out to individuals, and as Mr. Boutwell I think said, the volunteer efforts were truly heartwarming, truly amazing.

We have some preliminary figures on assistance to individuals. Two-hundred forty-four people received $131,000 for temporary housing assistance and that included 180 Wake County residents. One-hundred seventeen people have been approved for almost a million dollars in disaster loans from the Small Business Administration and 238 grants totaling $544,000 have been provided through the individual and family grant program for medical expenses as well as housing repair, personal property losses, transportation and funerals.

That governmental assistance then, plus the volunteer assistance, has helped many individuals deal with their losses and with their hardships, but the city has been frustrated in its efforts to receive assistance for debris removal.

Would you have anything to add on that about the range of assistance that has been available, your observations on that?

Mr. **Upchurch.** Well flying in the helicopter at approximately 5:30, observing the situation all in Franklin County, I had a good handle on what had taken place, and the City Manager was on board. I immediately asked him to declare an emergency condition so that we could place police officers in every area where damage had taken place immediately, keeping the looters out. We observed quickly that the storm was not a storm that destroyed infrastructure, it destroyed homes, it was personal property damage. And I saw quickly that the people were in need of help. And for us to sit in the streets and watch them, we could not do that. I instructed the Manager to move quickly to assist wherever we could. So we acted because it was time to act.

Well when the people came in from the federal government, it was a matter—it was form filling out time. It was a "let's make a deal" situation. It never was "how can we help". We had to respond. There was never any complaint from citizens that we helped them and got them out of a situation. Our information was "well you paid too much to do the job".

Well Congressman, you know, it is awful difficult when people are without homes—I went into the shelters and they were standing there with a shirt and pair of pants on, even their wallet had blown away, several people there, they were undressed in bed. People were in need. So we addressed the situation the best we knew how and we thought that fund in government was to assist. And I realize you may have assisted a few people, but I know hotels in the City of Raleigh probably assisted people that you have no record of. They gave them a place to stay, to live. So the volunteerism in this area, these other cities and towns that came to our rescue, they were calling from other states and wanted to come in here.

So the only agency of government that we found to be very difficult to deal with was our own federal government that has an agency that is supposed to assist people in disasters. So we are frustrated, and we remain—they never said well you paid too much, we will just help you this amount, they just packed their bags and left town. So I hope you see that I am concerned about this.

Mr. PRICE. I certainly do and we are as well.

As you said, one of the bright spots in this, and the report does bear this out, was in the area of preparedness.

Mr. UPCHURCH. The City Manager of Raleigh did go through an exercise. He must have had a premonition of this, approximately a year prior to this, and he had trained the people and when I was on the scene at approximately 5:00 a.m., at the command post, our fire chief informed me that they had made one swipe through the north Raleigh area even out into the county and were going back again. Now this was in total darkness, all the power was out. How these policemen and firemen and volunteer people were able to go through all those neighborhoods that quick is a miracle. So the reaction of the people that were trained—those 16 units that came in, they were plugged in, so to speak, and they had a duty or assignment. It was not confusion and chaos. So that is something to be reviewed if any interested party would like to know how to react when something happens, because it was a miracle.

Mr. PRICE. And there were many, many people who apparently knew exactly what to do when the storm was on them, so the efforts of education and training had paid off.

Mr. UPCHURCH. It certainly paid off.

Mr. PRICE. Let me recognize Mr. Valentine for whatever questions he might have.

Mr. VALENTINE. Thank you, Mr. Chairman.

Mayor Upchurch, do you feel that the door has been closed, your unfortunate experience with the federal folks?

Mr. UPCHURCH. Yes, sir.

Mr. VALENTINE. You feel—you do not think that maybe Congressman Price could go back to them and maybe explain it to them a little bit differently?

Mr. UPCHURCH. I would thank you for doing that, but from our perspective we have exhausted all the directions that we know to go, and therefore we were told that we paid too much for this service and we were not eligible. And I think we were told that we were financially capable of handling our own situation, and that is another low blow because we were trying to assist these people and do it quickly and we do not have extra millions of dollars in our budget that comes from our people like Ms. Moody's people and all of them.

Mr. VALENTINE. It eventually comes from the people.

Mr. UPCHURCH. Always. But we all—all citizens want to help each other in situations like this.

Mr. VALENTINE. I know that David did do everything he could do and will continue to, but could you let me sometimes at your—I do not want to add to your burden, but let me have a little note that gives some names and so on. I just would like to file that away so maybe we can see it does not happen again. I know that sometimes that kind of conduct can seem to add insult to injury.

Let me ask this question first of Ms. Moody. What would you have done in Rolesville if you—differently, if you had had notice? Now this tragedy occurred in the early morning hours when the normal way of advising people that there is a weather problem is radio and television and of course most people would not be listening to radio or looking at television at that hour.

But what—under these circumstances, what would have happened differently in Rolesville if you had had notice?

Ms. MOODY. If we could have known what area it was going through, we have enough volunteers through our fire and rescue and police officers with the Town of Wake Forest getting involved, to go door-to-door in this area.

Mr. VALENTINE. Well of course, the Town of Wake Forest would have had to use its people for Wake Forest, would it not?

Ms. MOODY. Well see, it was between the two areas. Neither town was really affected, but it was between the two areas. And I believe with all of us that we could have had their volunteers and ours too, plus their police department. We could have gotten to these people.

Mr. VALENTINE. Of course, the only warning that anybody could have received I suppose was that there might be a tornado. I mean nobody could have said it is coming down First Street and going to turn the corner and go down to Seventh Street, of course.

Do you have any kind of plan in Rolesville or do you have any kind of plan in Franklin County? Do you utilize any local tax money to address this type of tragedy?

Ms. MOODY. It has really not been discussed.

Mr. VALENTINE. You have never discussed in Rolesville what the town might do for itself without the federal government's assistance?

Ms. MOODY. No.

Mr. VALENTINE. Have you ever done that sort of thing in Franklin County, Mr. Boutwell?

Mr. BOUTWELL. Yes, sir, Congressman Valentine. We have an Emergency Management Office and we do have a disaster plan, which is, I guess, a fairly generic type of plan. However, with the forewarning, I think at that hour what would have been done by our forces would have been that the volunteer fire and rescue units as well as the paid police and sheriff's department would have been notified by the radios that they carry and the pagers that they have. As far as the kind of effort as far as tornadoes are concerned, I think for the most part they would just have to be on standby because of the nature of the way tornadoes hit. It would have been very difficult for them to have gone door-to-door in our area to warn folks, for example, just as you were describing, you do not know if they are going to hit or exactly where they are going to hit. But that would be the first thing that we would do is we would put it out on our police and fire communication system.

Mr. VALENTINE. Ms. Moody, has your governing body, you and the town council in Rolesville, discussed since this tragedy what you might do if it happens again?

Ms. MOODY. With the small amount of resources and the size of our town, the only thing that we really do have is our police department that is paid, the rest of us are all volunteers and with us being hooked into Raleigh, really utilizing their services that they have for warnings. The police officers have plans, you know, of what to do, but as far as practicing anything, we have not.

Mr. VALENTINE. One more—just one more word on that. What is the arrangement with Channel 5? Maybe you could tell us about that for the benefit of Channel 11.

Ms. MOODY. Okay.

[Laughter.]

Ms. MOODY. That does not have a thing to do with it. But they basically tell us—they are our dispatcher, we do not have an inhouse dispatcher but they dispatch us for weather warnings, they dispatch us when our police officer needs to go to a home, has an accident, et cetera.

Mr. VALENTINE. I do not have any further questions. Thank you all very much.

Thank you, David.

Mr. PRICE. Thank you. Mr. Mayor.

Mr. UPCHURCH. Congressman, I would like to make one observation and maybe this will plant a question later in the hearings when the weather people are here.

As I told you, at approximately 10:30, I took a stroll and I observed a problem. I toured the weather center some two years ago and they were showing me the sophisticated equipment and how they predicted the weather and then one of the gentleman said and then occasionally we go outdoors and check it out and see if we are right. I am not sure that he would like me to say that, but I am just wondering where they were that night, why they did not go outdoors and check it out, because I knew something was happening and I see oftentimes on the screen tornado warnings. The change in condition that night at around 10:30 alarmed me terribly and I can still recall the feeling in the air and the movement of the clouds, and I believe if I were—you are always an expert in another man's field but I believe if I had strolled outside of the weather bureau that night, I might have said you know, something is wrong.

Mr. PRICE. And your dog knew that something was wrong.

Mr. UPCHURCH. And my dog knew that something was wrong. The barometric pressure dropped so greatly that that dog was totally wild.

Mr. PRICE. I expect that a lot of people in this room have similar stories. I heard one account of a family that had recently moved here from Kansas, where of course tornadoes are much more common, and apparently earlier that evening the gentleman said,"You know, if I was in Kansas and not in North Carolina, I would swear a tornado was coming." There was something in the air; I felt it too. I think a lot of us did. And you have to wonder if there is not some scientific way of picking that up.

Mr. UPCHURCH. Well you can always go outdoors and check it out.

[Laughter.]

Mr. PRICE. Yes, that is right and that is one of the things that we will hope to explore with our Weather Service people.

Mr. VALENTINE. Well Mr. Mayor, are you suggesting that if they did not do that, they could at least go to the window and look out? Does your dog have rheumatism?

Mr. UPCHURCH. No. I know I am treading on thin ice in someone else's field, but I think it is something that needs to be asked because I have seen times when the weather did not show any indication of anything happening and I was being alerted to a tornado watch in effect. So maybe you can ask the question.

Mr. PRICE. Thank you. We appreciate the leadership all of you have offered over these difficult months and we appreciate you being here today.

Our next panel consists of two well-known TV meteorologists from local stations; Greg Fishel of WRAL-TV, Michael Caplan of WTVD-TV.

It is good to see you on the other side of the table. We will ask you to proceed, as we said with the previous panel, if you have extensive statements or attachments, we will be glad to include those in the record. We would appreciate you keeping your oral presentation to five minutes.

Mr. Fishel, we will start with you.

## STATEMENTS OF GREG FISHEL, METEOROLOGIST, WRAL-TV, RALEIGH, NORTH CAROLINA and MICHAEL CAPLAN, METEOROLOGIST, WTVD-TV, RALEIGH, NORTH CAROLINA

Mr. FISHEL. I appreciate the opportunity to be here. This is the third hearing that I have been involved in in this decade, two about tornadoes and one about droughts. I would like to see if we could arrange to do it about a happier affair at some point in time.

I was asked to pass along a comment from Chris Thompson from WPTF television who was asked to be here today as well. He had a prior commitment and could not be here, but he would like to be able to contact your office, perhaps next week, to add his comments.

Mr. PRICE. Yes, we had asked him to be here and we understood he had a conflict. We would be happy to have any comments that he would like to submit for the record.

Mr. FISHEL. Okay, good enough.

To try to summarize what I have in my written statement here, there have been two very devastating tornado outbreaks that have affected this state in the last decade. The one in March of 1984 was a little bit easier to see coming. We had talked about the potential of that storm 36 hours before the first tornado touched down, but this one was not quite so easy to see and it is understandable why anybody affected can say how can anybody miss anything this severe.

I think in response to Mr. Upchurch's comments just a few minutes ago, it is fair to the National Weather Service to say that we have had a lot of warm windy nights this winter since the tornado and people have called in and they say well it is just like it was in November of 1988 and why are you not forecasting tornadoes, and of course the reason was that we knew scientifically that the situation was not similar at all. So there are a lot of warm windy nights that lead to tornadoes and there are even more warm windy nights that do not.

On Saturday, November 26 of 1988, the National Severe Storms Center in Kansas City, which is responsible for issuing all the watches for the country—they issue what they call a Day-2 Convective Outlook where they try to take a look at the severe weather potential for the next day, and they did mention the possibility of severe thunderstorms, tornadoes in the Carolinas on Sunday and Sunday night. However, the parameters that they were looking at that day did not seem to materialize on the weather maps Monday morning—or Sunday morning, I am sorry—and so they then removed North Carolina from the area of concern. And that removal seemed very warranted due to the fact that all day Sunday and into Sunday evening, there were no reports of severe weather anywhere not only in North Carolina but for that matter the southeastern part of the country.

Now at 11:30 that night, Bill Schmidt, who is one of our meteorologists, went on the air and displayed the Charlotte radar which we get from the National Weather Service and it showed a large area of rain with thunderstorms embedded in that, heading toward the triangle. He did mention the possibility of strong thunderstorms with gusty winds, but at that time that was all that seemed warranted. We did not know how bad things were until shortly after 1:00 when Charlie Gaddy, our prime news anchor, got a call from a friend in Cary who had been monitoring a police scanner saying that there had been some sort of disaster near the Town Ridge Shopping Center. He then contacted our chief photographer and they got out there to see what had actually happened and we went back on the air at 2:12 a.m. that morning to begin broadcasting tornado warnings that had been issued by the RDU office for Franklin and Halifax Counties. That was the first time we were able to go on the air and disseminate any warning information.

Now Capitol Broadcasting Company, which owns WRAL-TV, has been very, very cooperative in my efforts to build a really nice weather office. We have access to all the meteorological weather data from the National Meteorological Center in Washington, D.C. We can look at 100 radars across the country including our own private phone line to three radars; Wilmington, Volens, Virginia and Raleigh. And it was the opinion of our meteorologists that night that the atmosphere over us was not ripe for an outbreak of severe weather, let alone killer tornadoes, and this thinking was consistent with the opinions expressed by the local National Weather Service office at RDU. So it is our opinion that they did the best possible job with the equipment and technology available.

Now a lot has been made about the fact that the radar was out, and admittedly that could not have helped the situation, but other radars nearby such as the one at Volens were monitoring the same area of thunderstorms and saw not even a hint of thunderstorm intensities needed to spawn even a small tornado, let alone a violent one.

Now we all hope that with NEXRAD, that we are going to get a lot more lead time on tornadoes, but until that happens, one can only do the best with what one has. Now it is certainly not my intent here this morning to make anybody a scapegoat. In fact, as has been mentioned earlier, I think the National Weather Service should be highly commended for their efforts to educate the public about tornadoes and tornado safety. Many people affected by the storm—and this came out in the report—were reported to have said that when they heard the sound of the roaring train, they knew what to do and where to go. Now Dennis Decker was hired after the 1984 outbreak as the Warning Preparedness Meteorologist for this local office and he spearheaded an effort to get the word out to all North Carolinians about tornado and tornado safety, and that probably saved more lives than any watch or warning could have that night. Obviously times like these are very troubling and disappointing, but they are opportunities to learn and that is indeed why we are here today.

Now in terms of what could be changed, what could be done better, one obvious recommendation that I would like to make is to do everything humanly possible to accelerate the implementation schedule for NEXRAD in North Carolina. We are not in tornado alley and we probably do not need this as much as some areas in the plains, but we know from this decade alone how vulnerable we all are to strong tornadoes.

Research like that going on at North Carolina State under the direction of Dr. Anderson, who we will hear from later this morning, should move aggressively forward searching for any clues that this most recent outbreak could reveal to us. However—and I want to read verbatim from the statement here because I want to make sure I make this point—I have a very large concern about any changes in the criteria required for the issuance of severe weather watches and warnings. The system used by the National Weather Service currently in terms of getting severe weather information out, is one that leads to unavoidable complacency on the part of the general public. This is through no fault of their own, it simply reflects the current state-of-the-art technology and knowledge. The average size of a severe weather watch is 26,000 square miles. That information comes from the National Severe Storms Center in Kansas City. And a warning may affect an entire county. Even if severe weather occurs within these regions, the majority of people within the defined area never see severe weather. Thus, it is natural after a number of years for one to say "I hear these warnings all the time and it has never happened to me." If we could pin the storms down more, obviously we would, but our network of upper air observations and current radar technology will not allow us to see the atmosphere with that much meticulousness.

The November 28 situation was one that appeared marginal at best for severe thunderstorm development. There were strong winds in the upper atmosphere and we had a lot of low-level moisture, but the lapse rate of temperature with height was not impressive and did not lead anyone to believe that such a disaster could have occurred. If we start issuing watches and warnings to the general public every time there is a slight chance of severe weather, we will do everyone a great disservice and increase the number of individuals that view the National Weather Service as a bunch of wolf criers.

Unless a specific and unique set of observations can be made through research concerning this particular storm, it is my recommendation that absolutely no changes be made to our current watch/warning procedures until NEXRAD is implemented.

As long as we move ahead in the education process that has been so effective in the last four years, I think the number of fatalities due to severe thunderstorms and tornadoes will continue to decrease. And in summary, it is my view that the National Weather Service did the best job with the tools available and since they are the ones who are responsible for issuing warnings, serious consideration should be given to each and every one of their requests concerning the availability and access to various types of meteorological data in a convenient and useful manner. Admittedly money is tight in the federal government, and no price can be attached to the loss of any life during such an event. If we need more people or better equipment, or both, let us do it. The return on that investment will be immeasurable.

One final comment which is not included in this record but I feel obligated to make, the Emergency Broadcast System, as I understand it, is set up to get important weather information like this out to anybody that obviously needs it. Now for radio and TV stations to have local weather wires, they do not need to worry about Emergency Broadcast Systems because they get the information directly from the Weather Service, but we can consistently beat Emergency Broadcast System by a great number of minutes at our station. Now that is fine for us, but competition is not supposed to be important in a situation like this. If a radio station does not have a local weather wire, they should be able to get that information out to their listeners and viewers as quickly as we do, and the current state of the Emergency Broadcast System will now allow that.

Mr. PRICE. Can you elaborate on that a bit? Why is that so?

Mr. FISHEL. Well I do not know. I am just bringing it up as an observation, but I do know that there have been several times where we have gotten a warning on the wire and we put it on the air and then our radio station, WRAL-FM has gotten the information from EBS four, five, six minutes later. As I understand it, the average lead time on a tornado in this country right now is one to two minutes. So if there is a delay of five minutes between when we are getting it and when it is going out over EBS, that can mean the difference between somebody living and dying.

[The prepared statement of Mr. Fishel follows:]

# COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
# SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE RESEARCH AND ENVIRONMENT
# U.S. HOUSE OF REPRESENTATIVES

## Tornado Forecasting & Severe Storm Warning

Testimony
by
GREG FISHEL
WRAL-TV

Submitted
March 1, 1989

North Carolinians have witnessed two devastating tornado outbreaks this decade -- one in March 1984 and the other on November 28, 1988. The 1984 outbreak was a lot easier to see coming as severe weather potential was mentioned on our station 36 hours before the first tornado touched down in North Carolina. This past November things were not quite so clear cut. It is understandable why some people would inquire "how could anyone miss a store so severe?" I will attempt to address that issue starting with a summary of how our television station handled the situation. I will then make a few observations about the National Weather Service, and finally, will make a few recommendations for the future.

On Saturday, November 26, 1988 the National Severe Storms Center in Kansas City issued a statement in their Day-2 Convective Outlook that mentioned the possibility of severe thunderstorms and tornadoes in the Carolinas on Sunday and Sunday night. However, the parameters that looked so threatening then didn't materialize quite so impressively on Sunday. As a result, North Carolina was removed from the area of concern. And that removal seemed very warranted throughout the day Sunday and into Sunday night as no severe weather was reported anywhere. At approximately 11:30PM, Bill Schmidt, one of our meteorologists displayed the Charlotte radar, courtesy of the National Weather Service, on our newscast and it showed a large area of rain with embedded thunderstorms heading toward the Triangle Area. Bill mentioned the possibility of heavy thunderstorms with gusty winds, but that was all that seemed necessary at the time. Shortly after 1PM, Charlie Gaddy, our prime news anchor, received a call from a friend in Cary monitoring a police scanner. The friend told him of a disaster that had occurred at Town Ridge Shopping Center on US 70 West in northwest Raleigh. Charlie then contacted Jay Jennings, our chief photographer, and they rushed to the scene. I was called at approximately 1:45AM to come in immediately, and we went on the air at 2:12AM to begin relaying tornado warnings issued by the National Weather Service Office at the RDU Airport for Franklin and Halifax Counties. We stayed on the air continuously for the remainder of the night relaying warnings and reporting on the loss of life and property.

Capitol Broadcasting Company, which owns WRAL-TV, has one of the best equipped TV weather offices in the country. We have access to all of the raw meteorological data provided by the National Meteorological Center in Suitland, Maryland. We also have a satellite animation system, and access to over 100 radars across the country, including continuous access to the radar displays at RDU, Volens, Virginia and Wilmington, North Carolina. It was the opinion of our meteorologists that the atmosphere over central North Carolina was not ripe for an outbreak of severe weather, let alone killer tornadoes. This thinking was consistent with the opinions expressed by the local National Weather Service Office at RDU. As a result, it is our opinion that the National Weather Service did the best possible job with the equipment and technology available. Much as been made of the radar being out at the time.

Admittedly, this couldn't have helped the situation, but other radars nearby were monitoring the same area of thunderstorms and rains and none saw even a hint of the thunderstorm intensities needed to spawn even a small tornado, let alone a violent one. With the coming of NEXRAD, or Next Generation Weather Radar, hope runs high that the National Weather Services will be much better able to observe severe storm signatures and give the public increasedlead time on severe weather occurrences. Until that happens one can only do the best with what one has. In fact instead of searching endlessly to make it a scapegoat, the National Weather Service should be highly commended for their efforts to educate the public about tornados and tornado safety. Many people affected by the storm were reported to have said that when they heard the sound of the roaring train, they knew what to do and where to go! When Dennis Decker was hired after the 1984 outbreak as the Warning Preparedness Meteorologist for the NWS Office serving the State of North Carolina, he spearheaded an effort to get the word out concerning tornadoes to as many people as possible, and that effort probably saved more lives than any watch or warning could have. Sure, we all wish we could have seen it coming, but we didn't. Times like these are very troubling and disappointing to say the least, but they are also opportunities to learn. We cannot change the past, but we can use the past to make the future better, and that should be the focus of this hearing today.

What should be changed? What could we have done better? One obvious recommendation is to do everything humanly possible to accelerate the implementation schedule for NEXRAD in North Carolina.

This decade alone has proved that North Carolina, although not in Tornado Alley, is certainly vulnerable to these types of storms.

Research like that which is going on at NCSU under the direction of Dr. Anderson should move aggressively forward, searching for any clues that this most recent outbreak could reveal to us. However, I have a very large concern abut any changes in the criteria required for the issuance of severe weather watches and warnings. The system used by the National Weather Service currently is one that leads to unavoidable complacency on the part of the general public. This is through no fault of their own -- it simply reflects the current state of our technology and knowledge. The average size of a severe weather watch is 26,000 square miles, and a warning may affect an entire county. Even if severe weather occurs within these regions,the majority of people within the defined area never see severe weather. Thus, it is natural after a number of years for one to say, "I hear these warnings and watches all the time, and it's never happened to me." If we could pin down storms more we would, but our network of upper air observations and current radar technology will not allow us to see the atmosphere with that much meticulousness. The November 28 situation was one that appeared marginal at best for severe thunderstorm development. There were strong winds in the upper atmosphere and the low level moisture supply was rich to say the least. However, the lapse rate of temperature with height was not impressive at all and did not lead anyone to believe that severe thunderstorms could develop. If we start issuing watches and warnings for the general public every time there is a slight chance of thunderstorms, we will do everyone a great disservice and increase the number of individuals that view the National Weather Service as a bunch of wolf criers.

Unless a specific and unique set of observations can be made through research concerning this storm, it is my recommendation that absolutely no changes be made to our current watch/warning procedures.

The NEXRAD system offers all of us great hope for the future with regard to tornado detection and prediction. That combined with the continuing education efforts of the National Weather Service, gives us good reason to believe that fatalities due to severe thunderstorms and tornados will continue to decline. The National Weather Service Office at RDU is one of the best in the country. They are not infallible, but they share that trait with the rest of civilization. It is my view that they did the best job humanly possible with the tools available. Since they are the ones who are responsible for issuing warnings, serious consideration should be given to each and every one of their requests concerning the ability to access various types of meteorological data in a convenient and useful manner. Admittedly, money is tight in the federal government, but no price can be attached to the loss of any life during a severe wether event. If we need more people or better equipment or both, let's do it! The return on that investment will be immeasurable.

Mr. PRICE. Thank you. Mr. Caplan.

Mr. CAPLAN. Thank you, Congressman Price, Congressman Valentine, other members of the Subcommittee.

I think it is important to recognize today that we in the television weather business are the primary disseminators of warnings and watches issued by the National Weather Service and the Severe Storms Forecast Center, so I appreciate you allowing us the opportunity to testify today.

My testimony reflects my own opinions as well as the opinions and responses of my colleagues at WTVD in the Weather Department, Lisa Patton and Bill Reh, who I both interviewed, and our thoughts reflect the general concerns of forecasting similar events in the future and also the aftermath of the November 28 event.

WTVD broadcasts two live news shows on Sunday nights, airing at 6:00 and 1:00 p.m. Lisa Patton is our regular weather anchor and was on duty from approximately 3:00 p.m. until shortly after our late newscast concluded.

During the weekends, and throughout the week for that matter, in order to develop our forecasts we rely on our own opinion as well as information provided by the National Weather Service, NOAA and a private forecasting service called Accuweather. In her conversation with Accuweather meteorologists Sunday afternoon, which is a regular procedure that we go through during the day, as kind of a forecast consulting period, Ms. Patton was advised of the possibility of severe thunderstorms in our viewing area later that night and Lisa indicated that threat on WTVD's 6:00 p.m. newscast.

As the evening wore on, the atmosphere appeared to stabilize somewhat and by forecast briefing time for our late new, Accuweather no longer raised a concern for severe weather in our viewing area. Ms. Patton mentioned the likelihood of a thunderstorm in her 11:00 report but augmented the forecast to minimize the severe weather threat.

Accuweather's opinion of the storm threat mirrored those of the National Weather Service at Raleigh Durham International Airport, whose local forecasts also downplayed any convective severity that night.

It must also be noted that a vital part of our weather presentation during any storm event at WTVD is the National Weather Service radar at Raleigh Durham Airport, which we are able to display live to our viewers. This utilization of the radar is precursed by our own monitoring of the radar screen at the station to keep tabs on any developing cells, their movement, their intensification. And on the night of the tornado outbreak, as we have heard before, that key instrument in our forecasting ability was out of commission and therefore greatly diminished the accuracy of Ms. Patton's forecast in the short term.

In addition, WTVD also enlists the aid of a network of weather watchers who regularly report weather events from their homes in big cities and small towns throughout our viewing area. In the past, especially last spring and summer, these weather watchers, exclusive to our station, have alerted us to the incidence of severe weather such as large hail, wind damage and funnel clouds and since we have been able to develop a symbiotic relationship, if you will, with the National Weather Service, we pass along those reports from our weather spotters to the National Weather Service and they have in turn been able to confirm radar echoes, issue warnings in a prompt manner. That night, none of our weather watchers noted any unusual phenomena prior to the tornado itself.

Shortly before midnight, Ms. Patton left Channel 11 and all appeared well until an hour later when the tornado touched down. Two of our employees live in one of the apartment complexes that was first hit, and our newsroom reacted immediately. We began airing live NOAA weather radio broadcasts over color bars so that any warnings that were issued by the Weather Service would be received in the most timely manner by our audience, albeit a small one at that late hour, and we were on the air continuously.

By about 3:30 in the morning, our meteorologist Bill Reh was on duty managing any crawls of pertinent weather information as they became available to us. In addition, WTVD cut into regularly scheduled programming at 5:00 and 5:30 a.m. to announce the situation and broadcast three consecutive live hours of coverage beginning at 6:00 a.m. to inform our viewers of what had happened and what was evolving.

Though no tornado warning was issued for Wake County, one cannot fault the personnel on duty at the Weather Service office. I agree with Greg certainly, the Severe Storms Forecast Center or anyone else for their actions that night. Blame falls first and foremost on the inexactness of the science of meteorology. However, there is a clear and glaring obsolescence in the radar being used at Raleigh Durham International Airport, a radar that in my opinion should be replaced as quickly as possible and relocated away from the airport.

The radar that we use has an enormous blind spot of ground clutter right over the triangle area and that is a key urban portion of our viewing audience, and therefore it is of less use than it could be for that portion of our audience. True, there is a radar site in Volens, Virginia which can effectively see through that ground clutter pattern, but that is in Virginia, not in North Carolina where our local experts can monitor it readily.

I therefore recommend that a new site be chosen for the radar. I understand that one has been in the Fuqua/Varena area. I think that if that is enacted quickly, the triangle will be more effectively monitored for severe storms. And this is irrespective of any future Doppler or NEXRAD plans. I am from Illinois and worked their prior to here, and there is a radar in Marseilles, which is in the north central part of the state, which was able to monitor storms in the Chicago area. If they were to locate a radar in Chicago itself, they would have the same problem that we have in the Raleigh/Durham/Chapel Hill area.

But even had we been able to draw upon such a radar arrangement on November 28, who would have seen or heard any tornado warning? It was late, few people were awake, much less watching television or listening to their radios. In my home state, emergency management officials use loud air sirens in the event of tornadoes, and to the beset of my knowledge there were no air sirens used that night. I do not know if there are any in place. If they are, they were not functioning as they should have been. Perhaps I should propose that sirens be installed and tested on a regular basis. We have heard about false warnings, but I think better safe than sorry and if a siren implementation program is coupled with a good public education program such as that which Dennis Decker has been able to provoke around here, I think that that might be very beneficial.

Until we better understand the complexities of tornado development, thus enabling us to give advance warning, not reactive warning, we are going to be a slave to our own ignorance so to speak. We in the weather business do the very best we can with the tools and the smarts that we have.

On the morning of November 28th, the inefficacy of one of our tools proved all too tragically that we need to replace and upgrade the radar at the Raleigh Durham International Airport.

Thank you.

[The prepared statement of Mr. Caplan follows:]

# Testimony From
# Michael C. Caplan
# On The Tornado Outbreak Of
# November 28, 1988

Submitted:
March 2, 1989

Let me preface my testimony by stating that I was not the weather forecaster on duty at WTVD during the day or night of Sunday, November ~~28~~ 27, 1988. My testimony shall reflect the opinions and responses of my colleagues Lisa Patton, and Bill Reh, whom I have interviewed, as well as personal thoughts in the aftermath of the torado outbreak and the more general concerns of forecasting similar events.

WTVD broadcasts two live news shows on Sunday nights, airing at 6 p.m. and 11 p.m. Lisa Patton is our regular weather anchor on weekends and was on duty from approximately 3 p.m. until shortly after our late newscast concluded.

During weekends, and throughout the week for that matter, WTVD relies on weather information provided by the national weather service, NOAA, and a private forecasting service , Accuweather. In her conversation with Accuweather meteorologists Sunday afternoon, Ms. Patton was advised of the posibility of severe thunderstorms in our viewing area later that night. She indicated that threat on WTVD's 6 p.m. newscast.

As the evening wore on, the atmosphere appeared to stabilize somewhat, and by forecast briefing time, Accuweather no longer voiced a concern for severe weather in our viewing area. Ms. Patton mentioned the likelihood of a thunderstorm in her 11 p.m. report, but augmented the forecast to minimize the severe weather threat.

Accuweather's opinion of the storm threat mirrored those of the national weather service at Raleigh Durham International Airport, whose local forecasts played down any convective severity that night.

It must be noted that a vital part of our weather presentation during any storm event at WTVD is the national weather service radar from the Raleigh office, which we are able to display live to our viewers. This utilization of that radar is precursed by our own monitoring of the radar screen at the station to keep tabs on developing cells that may evince themselves. On the night of the tornado outbreak that key instrument in our forecasting ability was out of commission, and greatly diminished the accuracy of Ms. Patton's forecasting, in the short term.

WTVD also enlists the aid of a network of weather watchers, who regularly report weather events from their homes in big cities and small towns across our area. In the past, these weather watchers, exclusive to WTVD, have alerted us to the incidence of severe weather such as large hail, wind damage, and funnel clouds. As a symbiotic relationship has been fomented between WTVD and the national weather service, we at WTVD have been able to pas these observations to forecasters at the Raleigh office, many times resulting in issuances of prompt warnings or confirmations of previously detected radar echoes. That night, none of our weather watchers noted any unusual phenomena.

Ms. Patton left WTVD shortly before midnight, and all was well until an hour later, when the tornado touched down. Since two WTVD employees lived in one of the apartment complexes first hit, our newsroom was notified immediately of what had happened, and by 3:30 a.m. Bill Reh, WTVD' s meteorologist had been called in. We ran font crawls of existing warnings and the tornado watch issued by the severe storms forecast center.

In addition, WTVD cut in to regularly scheduled programming at 5:00 a.m. and 5:30 a.m. to announce the situation, and broadcast 3 hours of live coverage from 6:00 a.m. on to inform our viewers of what had happened overnight.

According to Mr. Reh, tornado warnings for counties hit after Wake were issued by the NWS and broadcast in a prompt maner by WTVD, but no warning ever crossed the wire for Wake County.

In retrospect, one cannot fault any personnel at the National Weather Service at Raleigh Durham, or the Severe Storms Forecast Center for their actions that night. The problem first and foremost lies in the inexactness of the science of meteorology itself. However, there is a clear and glaring obsolescence in the radar used to monitor the Raleigh Durham area...one that must be replaced and in my opinion relocated away from the airport.

Since the existing radar has a distinct blind spot right over the key urban heart of our viewing area, it is of very little use to the majprity of our audience. True, there is a radar at Volens Virginia that can see through the ground clutter at RDU, but that's still in Virginia, not in North Carolina, where our local experts can monitor it.

I recommend that a new site be chosen for the radar, perhaps south of the airport, so that the triangle could be easily watched for severe storm development. This recommendation is irrespective of any future Doppler plans. An example of this rural monitoring of a key urban center is the Marseilles, Illinois radar, which effectively watches weather for the Chicago area.

But even had we benefitted from this arrangement on NOvember 28, who would have heard or seen the tornado warning? It was late, few people were awake, much less watching television or their radios. In Illinois, where I hail from, they used air sirens to alert people when tornado warnings were issued. When they went off, you knew to take cover and tune to the radio or tv. To the best of my knowlege, there are no air sirens in this area. Maybe there should be.

Until we understand better how tornados form, thus enabling us to give advance warning, not reactive warning, we will be a slave to ignorance. We in the weather business do the very best we can given the tools and smarts we have. On the morning of November 28th, 1988, the inefficacy of one of our tools proved all too tragically that we must replace and upgrade the radar at the Raleigh Durham weather office. If we can save four lives next time, is it not worth the cost?

Mr. PRICE. Thank you Mr. Caplan. Our thanks to both of you for some very helpful testimony.

Mr. Caplan, you talked about the various data sources that you have at WTVD, including Accuweather. Is that the correct name?

Mr. CAPLAN. Yes, sir.

Mr. PRICE. A private forecasting firm.

Mr. CAPLAN. Correct.

Mr. PRICE. Do you have a similar service that you draw on at Channel 5?

Mr. FISHEL. No, we basically are doing in-house what Accuweather would do up at their base office in Pennsylvania. We look at the data directly and analyze it and disseminate that forecast directly to the public.

Mr. PRICE. Well, what does Accuweather or a private service of that kind give you that the National Weather Service facilities do not? You say in this case their forecasts were essentially no different.

Mr. CAPLAN. Well Congressman Price, I can recall at least a half dozen instances last year alone when Accuweather, through their contacts with the Severe Storms Forecast Center, was able to tip us off to issuances of tornado and severe thunderstorm watches which we then were able to get on our air at least ten to fifteen minutes before anything cross the weather wires in our office. So they have been able to get the word out to us quicker than would have normally happened.

In addition, we use Accuweather as a secondary source of information, another opinion to bounce back our own thoughts and at times we take what Accuweather says and discard it if we disagree with it vehemently. Other times, they bring up a good point that maybe one of us at the station has overlooked and we will go with that.

Mr. PRICE. But you say there are a number of instances where they have come in with the information earlier?

Mr. CAPLAN. Yes, sir.

Mr. PRICE. And in your judgment more accurately?

Mr. CAPLAN. In the issuance of a watch, not necessarily more accurately, just quicker than would normally have taken place.

Mr. PRICE. What accounts for that? Is it equipment that they have that the Weather Service does not, some other communication capability? How would you account for that?

Mr. CAPLAN. Well to the best of my understanding, the Accuweather meteorologists who are in contact with the Severe Storms Forecast Center, if someone there decides they are about to issue a watch for our area, during the course of their conversation on the phone with the Accuweather people, they may say "well we are going to go out with a watch at 3:00 this afternoon and here is the area that will be governed under that watch." Accuweather will then promptly call me or whoever is on duty at Channel 11, tell us they are going to go out with a watch, here are the counties that will be affected in your viewing area. We get that information then typed up, put on a crawl over our live programming and in at least half a dozen instances, that beat the actual issuance of the watch as it came across the weather wire.

Mr. PRICE. Mr. Fishel.

Mr. **Fishel**. Just a comment on that. The domestic data line, which is one of the data communications systems provided by the National Weather Service to data users like us, issues watches in a two-part process. They send over what they call a preliminary watch, which will basically tell you that this watch is going to affect these states, it will be so many statute miles either side of a line from dot to dot and that will come out many times 30 to 40 minutes before the actual watch goes into effect. Now we do not get a county outline that early, but we will get that and we will draw it up roughly on a map and if we know we are going to be in it, then we will go ahead and run the crawl. Usually what we will do though is wait for the National Weather Service to send us the aerial county outlines so we know specifically what counties will be involved and what will not. But they do send that preliminary statement many times half an hour in advance so that at least we know something is coming.

Mr. **Price**. Are the two of you in agreement that even if the Raleigh Durham system had been up and working properly—

Mr. **Caplan**. The radar?

Mr. **Price**. The radar. —it would not have measurably increased your ability to give a warning in this case? There seems to be some slight discrepancy in your statements on that point and I need to clarify that.

Mr. **Fishel**. It is a tough thing to address. I have—if I am remembering correctly, a few years ago there was a man in Zebulon I believe that was killed on a Sunday night by a tornado that never showed up on the radar as being that strong. This seems to be a trait of tornadoes in the eastern part of the country, they do not show up on radar nearly as well as they do in places like Oklahoma and Kansas. So there is a precedent for tornadoes killing people and damaging property and no signature shows up on the radar that is available to us now.

It is sort of a moot point I guess because it was not in operation, so we will never know what it would have shown, but I think I would have to say that I have good reason to believe that even if it had been in operation that night, it might not have done us any more good than it did without it. The Doppler radar, which is actually going to be able to show us motion of raindrops as opposed to just the pure detection of it, many times in the nation's mid section has given up to 20 minutes lead time—not all but some—in terms of if you see a whole bunch of raindrops moving away from you real fast here and right next to you they are moving toward you real quick, you know you have got this. And I think that is the thing that is going to allow us to detect some of these storms that right now we cannot.

Mr. **Price**. Now the ground clutter problem complicates this. Would the ground clutter be an equally severe problem with the Doppler system?

Mr. **Fishel**. I am probably the wrong person to ask since I am not a radar expert. I do know, having operated a radar a little bit when I was at Penn State, that you can raise the radar beam a little bit. Now that does not eliminate the ground clutter problem entirely but it does enable you to look at the vertical structure of a thunderstorm even when it is that close by, as I understand it. So the ground clutter does not completely kill your ability to look at the storm, it hampers it but you still are able to look at vertical structures that exist very close to the site.

Mr. PRICE. Mr. Caplan, you seem to be suggesting that because the ground clutter, the number of buildings and structures in the Raleigh/Durham vicinity, you would recommend moving the facility out of that area into some rural area where that ground clutter would not be as significant a problem.

Mr. CAPLAN. Well you never know when the next—and where the next tornado or severe weather event is going to strike. I suppose that it is inherent that all radars have a ground clutter problem, and if you put one in Fuqua/Varena, who is to say that two years from now there might not be a tornado that hits right on top of Fuqua/Varena. But given the fact that the urban center, if you will, is in the triangle area, at least in the area that we are talking about here, the fact that we have a blind spot in that area I think greatly diminishes my ability to see any type of severe weather. True, as Greg pointed out, at the Weather Service Office, they can do a vertical tilt survey of any storm and we will see when they do that since our radar is basically exactly what they are seeing. We have a live link with them. But then once they do a vertical tilt, you lose anything that is farther out of range, you only see close in. So while we might be seeing the thunderstorm that is on top of Durham, we will be missing the one that is hitting Lillington. So it is a double-edged sworn.

Mr. PRICE. There is a trade off there. How large is this blind spot, as you call it?

Mr. CAPLAN. I am not sure how many square miles, but it covers most of Raleigh, Durham and Chapel Hill and also part of Chatham County, the eastern part of Chatham County, so it is a good chunk.

Mr. PRICE. Mr. Valentine.

Mr. VALENTINE. Thank you, Mr. Chairman.

Mr. Caplan, Illinois would be one of those states where tornadoes are prevalent more or less, would it not?

Mr. CAPLAN. More frequent.

Mr. VALENTINE. At least to a much greater extent than eastern North Carolina. Can you tell us a little bit more about this siren warning device? What is the—is there a difference between when a siren goes off in the night that is a fire or a tornado or—in places where that mechanism is used, how is it handled?

Mr. CAPLAN. Congressman Valentine, I never heard a siren in Illinois used for a fire. It is a loud air siren, it almost sounded like—exactly the same thing as an air raid in any of the world wars that I have seen movies of. They would test these sirens every first Tuesday of the month at 10:00. So it was a given that there would be a test alarm done, and in most of the county seats in any event there would be, close to the emergency management offices on top of a building somewhere, they would have a siren which would go off any time they were appraised of a tornado warning.

Mr. VALENTINE. What did they do when there was a fire? There are plenty of sirens in this part of the country, but they are used to summons volunteer fire departments in most areas. What was used in these areas of Illinois in case you had a fire and you had to get the volunteer fire department together?

Mr. CAPLAN. I am not certain of that, but I would imagine that there would be perhaps sounding the siren twice, some sort of—okay we are going to have for the volunteer fire department, we will just blare the horn two or three times. If it is a tornado warning, we will have it on continuous blare. Really I cannot say with any degree of certainty how they differentiated between a volunteer fire alarm and severe weather warnings though.

Mr. VALENTINE. You do have a problem—I think that what Mr. Fishel mentioned awhile ago, the person—was not the person killed by—was not his automobile turned over or something?

Mr. FISHEL. Yes.

Mr. VALENTINE. The person that you mentioned was killed in a tragedy of this kind some time ago, and there was no warning. We are involved with storms which have different and strange propensities, are we not? This thing—a tornado, at least those that we have had experience with here, is it fair to say that first of all they are smaller, that they move around in the upper atmosphere and just kind of bounce around whereas other storms do not come on us in that manner?

Mr. FISHEL. Yes. It is just one of these things where, you know, we have already mentioned that the United States has more of a likelihood of seeing tornadoes than any other nation in the world, but within the United States, the central part of the country has classic variables that all come together many times a year to produce tornadoes that are very easily observed on radar. And unfortunately there is not always a correlation between violent winds and strong returns from the radar. A strong return on a radar is basically because if the radar beam goes out and bumps into a great number of raindrops then a lot of the radar beam then comes back to you and you see a strong return. Sometimes we get into a bad habit I guess of saying well on a scale of 1 to 6, we are not going to really take this seriously unless we see a level 6 or a level 5. And on this particular night, at least based on the reproduction that we were looking at, I never saw anything higher than a 3 or a 4. So there is obviously not a set relationship between rainfall intensities and wind damage and tornado potential, and that is why the Doppler is so important because it gives us a look at that wind profile and it starts to get us away from this thinking of heavy rain and severe weather correlating, which they do not do.

Mr. VALENTINE. The person at Raleigh Durham Airport to whom you referred in your earlier testimony as having some responsibility in connection with preparing people for catastrophe, was not that person employed there or that position filled after we had that 1984 hearing?

Mr. FISHEL. Absolutely, yes. I mean I sat here in front of you in 1985 talking about that outbreak and, you know, the spotters' network came about as a result of that and an increased awareness and education effort and I still feel like a lot of what came out of that hearing is the reason why we only had four deaths in this situation. Not that four is not bad, but considering the amount of damage that we observed, four is amazing.

Mr. VALENTINE. Let me ask both of you one final question that has—that is a matter that I have puzzled about. Why were there no fires? You know, this was a cool period, not cold weather, but a cool period of time and usually when this type of disaster strikes, the wires fall down on houses and gas mains are ruptured and coal burning, wood burning stoves are toppled over. But I do not remember hearing of any of the first flame or first puff of smoke that was connected with this tragedy.

Mr. CAPLAN. That is a tough one.

Mr. FISHEL. I do not know what to say about it. The only thing I heard was that the display of lightning that people near the tornado site observed was almost continuous, but I do not know how to answer the rest of it—I do not know.

Mr. CAPLAN. I did not hear of any gas mains that had broken. I do not think that it is a necessary correlation that when you have a tornado that you are going to have fires break out as well. True, there are times when you have downed power lines in any type of windstorm that can touch off fires or that the lightning will—

Mr. VALENTINE. Yeah, but anything that just topples over houses and moves things around, you would expect to upset stoves. That is just a real puzzle to me.

Mr. CAPLAN. Well I suppose one could speculate that at the time, I think the ground was already wet here and the fact that there frequently accompanies a tornado, a strong rain shaft, that may have had some negating effect on any would-be fires. That is speculation.

Mr. PRICE. Gentlemen, your testimony is very helpful. Thank you.

We now call our third panel, a panel of federal officials. Ronald McPherson, Deputy Director of the National Weather Service; Robert Muller, Meteorologist in charge of the Raleigh Durham Weather Service and Frederick Ostby, the National Severe Storms Forecast Center.

Ronald McPherson, we will start with you.

## STATEMENTS OF RONALD MCPHERSON, DEPUTY ASSISTANT ADMINISTRATOR FOR WEATHER SERVICES, NATIONAL WEATHER SERVICE; ROBERT E. MULLER, METEOROLOGIST IN CHARGE AT RALEIGH-DURHAM WEATHER SERVICE OFFICE and FREDERICK P. OSTBY, DIRECTOR, NATIONAL SEVERE STORMS FORECAST CENTER

Mr. MCPHERSON. Thank you.

Congressman Valentine, Congressman Price, I want to thank you for the opportunity of testifying before this hearing on the event of the tornado that caused such destruction in the Raleigh, Durham area and other parts of North Carolina.

The tornado event imposed a very severe stress on the warning system of the National Weather Service, with the result, as has been noted before, no warning was issued to the public before the tornado occurred. Our current technological capabilities did not allow us to either predict the development of the tornado in advance, nor to detect the tornado once it had formed in the Raleigh Durham area.

Thunderstorms were expected in the Raleigh Durham area that evening and early morning and in fact were included in the local forecast. Our staff of forecasters at the Raleigh Durham office was closely monitoring the situation, using information which they had available to them from the National Weather Service network radars at Volens, Virginia, at Wilmington and Cape Hatteras in North Carolina. They also had available to them satellite information.

The radar observers at the network radar sites did not detect any patterns in those radar signals which would suggest severe thunderstorms. Thunderstorms indeed were clearly indicated on all of those radars, but there were no indications of activity reaching severe levels.

In addition to the staff at Raleigh Durham and the surrounding stations, our forecasters at the National Severe Storms Forecast Center in Kansas City were closely following the events in North Carolina and after closely monitoring those events in the evening hours of Sunday night and the early morning hours of Monday morning, concluded that severe thunderstorms were not likely to form. This was in accordance with the view of the Raleigh Durham forecasters and other meteorologists, the television meteorologists whose testimony you have just heard.

Now the Raleigh Durham radar, which is known as a local warning radar and which fills a supplementary role, backup to the National Weather Service network radars, was inoperative during that time, as has been noted before. Our normal procedures for repairing such radars is that they are repaired during normal working hours, as a matter of cost efficiency, unless severe weather is expected. But severe weather was not expected that Monday morning and consequently the accelerated repair of the radar was not initiated.

There has been discussion earlier in this hearing in previous testimony about whether or not it would have made very much difference if the Raleigh Durham radar had indeed been operational. As has been noted, the tornado itself formed within the ground clutter pattern of the Raleigh Durham radar. Weather in general within 10 to 15 miles of any radar, any of our current radar, is very difficult to detect due to interference by the ground clutter pattern.

So the tornado was neither detected nor forecast by our present capabilities, and this is due to the limitations in our ability to observe the atmosphere and our ability to deliver the information to our forecasters, and it is also due to shortcomings in our understanding and the level of science with regard to the mechanisms for severe weather such as occurred in this event.

The National Weather Service has embarked on a very massive and expensive effort to address these and other technological shortcomings through a modernization of our operations. This has been going on for about the past decade. During that time the Department of Commerce, working with the Departments of Defense and Transportation have developed and are in the process of implementing a new nationwide network of Doppler radar systems which have been referred to in previous testimony as NEXRAD. The first operational unit is scheduled to be installed in Oklahoma early next year. Over 100 units will be coming on line across the country by the middle 1990s and as has been noted, the planned delivery date for the Raleigh Durham NEXRAD is December 1992.

Additionally, as part of the modernization effort, we are planning to place hundreds—in the vicinity perhaps of a thousand—automated weather stations across the country to fill in the gaps in our knowledge of our observation network. These gaps exist primarily now because under present circumstances the observations require people to make those observations. It is a very labor-intensive operation and therefore very costly.

Another vital part of our modernization effort is the development of more powerful computer systems in the local offices, such as Raleigh Durham, that will enable forecaster, local forecasters, to assimilate the information from the Next Generation Weather Radars, from the satellites, from the automated surface weather observing systems and other sources of information more effectively and more efficiently. These computers will not replace the forecasters, but they will serve as a powerful tool to assist the forecasters in discharging their job.

Mr. PRICE. Are you referring to the automated weather interactive processing system that we have reference to in the report?

Mr. MCPHERSON. I am indeed, Congressman—yes, sir.

The downside of the Weather Service performance in this occurrence was the fact that no warning was issued. Our technological capabilities did not permit us to do that. The positive side, which has been referred to also in previous testimony, is the warning and preparedness activity that has occurred in this area since the March 1984 outbreak. The disaster survey report indicates, in the interviews with survivors of the disaster, that they knew what to do, either from the media or directly from National Weather Service preparedness activities. And this we are convinced contributed to the low loss of life in this very serious episode.

So in summary, we recognize that we have limitations in our warning system now, we also believe that if the planned modernization of the Weather Service is implemented in a timely fashion, that we will see vast improvements in our capabilities for predicting this kind of event in the future.

Thank you.

[The prepared statement of Mr. McPherson follows:]

## TESTIMONY OF

RONALD McPHERSON
DEPUTY ASSISTANT ADMINISTRATOR FOR WEATHER SERVICES
NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

BEFORE THE

SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE
RESEARCH AND ENVIRONMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

MARCH 3, 1989

Mr. Chairman and Members of the Subcommittee:

In the early morning hours of November 28, 1988, a tornado touched down in north Raleigh and began an 84 mile march to the northeast. No warning was issued to the public before the tornado tore through Raleigh. Our current technological capabilities did not allow us to predict the development nor detect the tornado.

Our staff of forecasters at the Raleigh office was closely monitoring the situation using information received from nearby network radar stations, satellites, and other observational data. The network radars used were located at Volens, Va., Wilmington, and Cape Hatteras. Our highly trained radar observers at these sites did not detect any patterns which pointed to tornado development or occurrence before the tornado touched down in Raleigh. During the life of the tornado, radar and satellite data never definitely indicated that severe weather was occurring. Though some data began to hint at the potential for severe weather, this data was not made available to the forecasters until many minutes after the tornado struck. Our present technology does not accommodate rapid dissemination of observed data.

In addition to the staff at Raleigh and surrounding stations, forecasters at the National Severe Storms Forecast Center (NSSFC) in Kansas City were closely following events in North Carolina. After careful analysis of the weather over central North Carolina that night, the NSSFC forecasters concluded that severe weather was not likely to form. This view was shared by the Raleigh forecasters.

The Raleigh radar, which fills a supplementary role such as backing up network radars, was down awaiting parts. Such radars are repaired during normal working hours unless severe weather is expected. Since severe weather was not expected that Monday morning in late November, accelerated repair of the radar was not initiated.

Even if the Raleigh radar had been operational, it is questionable whether the tornado would have been detected. Weather within 10-15 miles of any radar is difficult to detect due to interference by ground clutter, and the November 28th tornado touched down within 4 miles of the radar.

The tornado was neither detected nor forecast because of present day limitations in our ability to observe the atmosphere and to quickly deliver this information to our forecasters. These shortcomings have also limited our understanding of many severe weather producing mechanisms present in the atmosphere.

The National Weather Service has embarked on a massive effort to address these and other shortcomings through a modernization of operations. For the past decade, the Department of Commerce has been working with the Departments of Defense and Transportation to develop and install a new nationwide network of Doppler radar systems to replace our aging radar network. The Next Generation Weather Radar (NEXRAD) network is the result of this effort. The first operational unit is scheduled to be installed in Norman, Oklahoma, early next year with over 100 units coming on line across the country by 1995. The planned delivery date for the Raleigh NEXRAD is December 1992.

Additionally, we are planning to place hundreds of automated weather stations across the country to improve our knowledge of present weather conditions. Currently, "gaps" appear in our observation network. These gaps exist primarily because, under present conditions, required observations are quite labor intensive and, therefore, too costly to fully support.

Another vital part of our modernization effort is the development of more powerful computer systems to be placed in our local offices and national forecast centers. These new systems will allow us to utilize fully the new data and make it available quickly to our forecasters. Computers will not replace forecasters, but will be powerful tools to aid them in the assimilation of the great volumes of new information.

There is encouraging news from the disaster which explains the surprisingly low loss of life. After the March 1984 North Carolina tornado outbreak, the NWS placed a Warnings and Preparedness Meteorologist (WPM) at the Raleigh office. A WPM's job is to educate the public, local governments, the media, and other organizations concerning severe weather and to provide instruction on how to protect life and property. Many of the Raleigh tornado victims told the NWS survey team that, even with little time to react, they knew what to do to protect themselves and their families. Asked how they knew, many said they had learned from the media or directly from the NWS preparedness efforts. We are convinced that the mercifully low loss of life in this devastating event was due to the efforts of the Raleigh warning and preparedness program.

In summary, present day limitations in technology which restrict our ability to adequately observe and understand the atmosphere resulted in no watch or warning being issued for the November 28, 1988, tornado. If the total NWS modernization plan is implemented, the result will be vast improvements in predicting deadly severe weather.

Mr. PRICE. Thank you very much. Mr. Muller.

Mr. MULLER. Congressman Price, I want to thank you and Congressman Valentine for being here for this hearing that affects people in the state that I am providing and responsible for the weather products that are issued in this state. You have my written testimony and you also have the survey report. My testimony will detail the activities that went on in the forecast office during the night of November 28.

I would like to emphasize a few facts about the relationship of this tornado to the 1984 tornado. On March 28 of 1984 we had another outbreak of tornadoes in North Carolina. Those storms killed 44 people, yet they were not as strong as those of November 28. The 1984 storms affected mainly rural areas, while the 1988 storm struck a residential area of a major city. In 1984 there was one death for every 21 homes destroyed while in 1988 there was one death for each 107 homes destroyed. In 1984, there were 15 warnings issued during that night and in 1988 there were only three warnings issued. The difference in 1988 was the presence of a warning preparedness meteorologist and an effective tornado awareness program.

Since 1985, the National Weather Service in North Carolina has conducted an intensive public information campaign aimed at teaching people how to recognize the tell tale sounds of a tornado when it is approaching, and what steps they can take for their personal safety. This was taught in elementary school and these children brought this information home to their parents. Special articles were featured in magazines, newspapers and other media. Special programs were prepared by television meteorologists and journalists on television and radio, providing information to the public on how they too could take steps to protect their lives during a severe storm occurrence, whether it was preceded by a warning or not.

In 1984, we had warnings out, but the public did not know what to do. In 1988, they knew how to react to severe weather and this saved many lives.

In summary, I believe the Raleigh staff did the best they could with this rapidly developing and fast moving severe weather event. The citizens of Raleigh knew how to protect themselves when disaster threatened. I firmly believe that our preparedness efforts made a significant contribution to the public's response.

[The prepared statement of Mr. Muller follows:]

# TESTIMONY OF

ROBERT E. MULLER
METEOROLOGIST IN CHARGE AT
THE RALEIGH-DURHAM WEATHER SERVICE OFFICE
NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

BEFORE THE

SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE
RESEARCH AND ENVIRONMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

MARCH 3, 1989

Mr. Chairman and Members of the Subcommittee:

An explosively intensifying and rapidly moving tornado developed near the Raleigh-Durham Airport around 1 a.m., on Monday, November 28, 1988. There had been no evidence of severe weather during the past 24 hours with this weather system and none was forecast.

Thunderstorms, with possible heavy rain, had been forecast by the previous shifts. The shift supervisor was watching these storms as they approached the north-central area of North Carolina. The local use radar was out of service and the staff was using a remote TV transmission of a network radar image from Volens, Virginia. The shift supervisor was also in phone contact with the Meteorological Technician on duty at Volens to obtain a verbal description of the storm.

At 1 a.m., the Volens radar observer reported a strong thunderstorm over Raleigh-Durham Airport, but the radar display did not show indications of tornado or severe thunderstorm activity with this thunderstorm. Around 1:15 a.m., reports of damage and possible tornadoes were received at the office. These reports could not be confirmed. Ten to fifteen minutes later, the number of calls inundated the three persons on duty with information.

Due to a phone line tie-up at the Volens radar site, it was no longer possible to dial up pictures from the radar station. The forecaster had to depend on verbal descriptions of the radar imagery from the Volens radar observer who reported that the storm had lower cloud tops and had decreased in intensity level from the time that the damage had been first reported. The shift supervisor deduced that the storm had weakened, and a Special Weather Statement advising the public was issued. At the next incoming report of severe weather, the forecaster on duty then issued a warning for Franklin County and later for Halifax County.

Severe weather warnings are issued on the basis of reliable spotter reports of severe weather or on the basis of radar imagery if there is an identifying radar signature occurring. In situations where a severe weather watch is in effect and a thunderstorm, even one nearing a severe category, is detected or reported, we issue a warning in order to minimize the risk to the public.

At the time of the tornado, there was no severe weather watch in effect and severe weather was not expected. Since none of these warning conditions was met, it was logical for the forecaster to try to obtain confirmation of the earlier reports of the storm, either by talking to other information sources or by coordinating with the Volens radar station.

The Raleigh-Durham National Weather Service radar had gone out of service the preceding week. The maintenance staff was notified and asked to repair the equipment. Parts were ordered, but because of the radar's age, they had to be modified before they could be installed. This, unfortunately, did not correct the problem. The Raleigh radar is a "local warning radar" and is used to augment the 24-hour a day coverage provided by our "network" radars. Since we are not part of the national network of 24-hour-a-day manned radars and because no severe weather had been forecast, troubleshooting maintenance was delayed until after the Thanksgiving weekend. This was undertaken that Monday, and the radar was operational by Tuesday.

The tornado first developed and touched down in the local warning radar ground clutter pattern. It would have been extremely difficult to pick up a tornado signature with a storm in the ground clutter pattern with this type of radar even if a tornado signature had existed with this storm. There had also been no previous history of severe storms in the Carolinas with this system. Thus, this was virtually an unwarnable situation at the onset of the severe weather.

On March 28, 1984, we had another outbreak of tornadoes in North Carolina. Those storms killed 44 people, yet they were not as strong as those of November 28, 1988. The 1984 storms affected mainly rural areas while the 1988 storm struck a residential area of a major city. In 1984, there was one death for every 21 homes destroyed while in 1988, there was one death for each 107 homes destroyed. In 1984, there were 15 warning issued in North Carolina, and in 1988, there were only three warnings issued. The difference in 1988 was the presence of a Warning Preparedness Meteorologist and an effective Tornado Preparedness Program.

Since 1985, the National Weather Service in North Carolina has conducted an intensive public information campaign aimed at teaching people how to recognize the telltale sounds of a tornado when it is approaching and what steps they can take for their personal safety. This was taught in elementary schools, and the children brought the information home to their parents. Special articles were featured in newspapers and in printed mailouts to the media. Special programs were broadcast on radio and TV providing information to the public on how they could take steps to protect their lives during a severe storm occurrence whether it was preceded by a warning or not. In 1984, we had warnings out but the public did not know how to react to the severe weather. In 1988, they knew what to do and this saved many lives.

In summary, I believe that the Raleigh staff did the best they could with this rapidly developing severe weather event. The citizens of Raleigh knew how to protect themselves when disaster threatened. I firmly believe that our preparedness efforts made a significant contribution to public's response.

Mr. PRICE. Thank you, Mr. Muller, and we will insert your full statement in the record. I wonder though, before we move on to our next witness, if you could just briefly summarize your conclusions with regard to the failings at Volens, Virginia and also some of the details about the equipment being down at Raleigh-Durham. I notice you do touch on that in your statement, and I wonder if you could just summarize that information for us?

Mr. MULLER. Certainly. Our radar, as Dr. McPherson has stated, is a local warning radar which means we are backed up by network radars and in case they go down we would become a network radar. In this case, Volens, Virginia, Wilmington and Cape Hatteras, the network radars were operating and our radar was down.

Our meteorologist was in contact with the Volens, Virginia office. As a matter of fact, at midnight when he entered on duty, he called Volens and alerted him to the fact that our radar was still down and asked them to continue to watch because we knew the thunderstorms were approaching the Raleigh-Durham area.

At 1:00 the Volens observer reported a strong thunderstorm over Raleigh-Durham, but the radar display did not show indications of any severe weather or tornado activity. At that time there was a thunderstorm going on at the airport, which was forecast to occur. By 1:15, we started receiving reports of wind damage. Our meteorologist on duty at the airport called the Volens office. By that time we were unable to dial up the radar at Volens any longer because of the phone tie-ups that go into the Volens area. Our telephone contact depends upon a telephone dial-up to the Volens radar. We do not have a dedicated line to that network.

Mr. PRICE. That tie-up occurred because of the number of people trying to call in and get that information?

Mr. MULLER. I really could not say what the reason was for tying up at Volens was, whether it was a telephone problem or unable to connect because of additional lines coming in, probably both.

Mr. PRICE. But there is no dedicated line?

Mr. MULLER. There is no dedicated line to Volens.

Mr. PRICE. And so at the most critical moment, you were not able to dial up Volens?

Mr. MULLER. That is right. The person on duty at Volens discussed the storm to our meteorologist, explained the storm had weakened in intensity and the tops were now lower, so our person assumed that the storm that he was hearing the reports of wind damage had therefore weakened and he issued a public weather statement and issued this on the NOAA weather wire and transmitted this on NOAA weather radio. Additional reports came in after this time with additional reports of severe wind damage. At the first report of additional damage, he immediately issued a severe weather—or a tornado warning for Franklin County and that went out on the NOAA weather radio with a tone alert alarm at 1:45 in the morning.

Mr. PRICE. And the storm entered Franklin County at what time?

Mr. MULLER. I believe at about 1:45 in the morning.

Mr. PRICE. All right, we will come back to some of this in the period that we reserve for questions.

Mr. Ostby.

Mr. OSTBY. Thank you, Congressman Price, Congressman Valentine. I appreciate the opportunity to be here this morning and I would like to comment before I give my testimony that I appreciate the previous support that we have had over the years from this Committee, at least on two occasions, visits to Kansas City by members of this Committee, your colleagues and former colleagues, Mr. Larry Wynn, a former Congressman from my State of Kansas, and Mr. Glickman of Kansas and Mr. Fuqua from Florida, and those interactions with us have been very helpful in the past and I think have had a great deal to do with some of the upgrades to some of the technology that we have been able to have out in Kansas City. I just want to say that we appreciate that very much.

The Raleigh tornado was a rare event considering the geographical area, the time of day and its extreme intensity. Prior to this episode, records dating back to 1916 indicate there has never been a November tornado that killed anyone in the State of North Carolina. In fact, our records show that in the past 35 years, there have only been three tornadoes in November that have been as intense as that Raleigh tornado. Neither a watch nor a warning was issued before the tornado struck, as you all know. This was due in large part to our present limited ability to sample the atmosphere in three dimensions and to take a pulse of rapidly developing small scale, what we call mesoscale, storm systems.

Tornado and severe thunderstorm watches are issued by the National Severe Storms Forecast Center in Kansas City, of which I am the Director, and they are intended to alert the public as to the potential for the development of severe weather. And I might add, to clarify some of the comments that came out earlier by Mr. Caplan, that our watches go to everyone at the same time. We do not single out any private entity for advanced information. Of course to do that would be quite improper. So our watches go to everyone at the same time. If anyone gets any information ahead of time, it is our own local National Weather Service offices because it is necessary for us to discuss the possibilities of the watch and to coordinate just how we are going to orient the watch and the time we are going to begin and the time we are going to end. So there is no prior interaction with any other kind of entity.

Mr. PRICE. Well since you raised the matter, let us just explore it for a moment. What would then account for a private company like Accuweather getting the information out earlier? Do they have an independent capacity to generate this information?

Mr. OSTBY. I do not think they receive—well, I am sure they do not receive the information any sooner than our National Weather Services offices.

Mr. PRICE. That is right, but do they have an independent capacity to generate comparable information?

Mr. OSTBY. No, they do not. I do not believe they do. They take our information and in those cases of watches, pass those along. They do not attempt to modify it or change it in any way, to my knowledge.

Mr. PRICE. So it is a communication capacity that we are looking at perhaps?

Mr. Ostby. That may be what has been happening, yes. But as far as how we issue it and to whom, it goes to everybody at the same time. It is broadcast, it is not narrow cast.

Mr. Price. I see.

Mr. Ostby. On the other hand, the tornado and severe thunderstorm warnings are issued by field offices, such as the Raleigh office. And in that case, the warnings demand immediate response as they signal that severe weather is either occurring or is imminent.

Another part of the Weather Service warning program is our warning preparedness and coordination efforts that attempt to ensure that local decision-makers and the general public understand the watch and warning information available to them and how to take safety precautions when severe weather threatens. The miraculously low death toll in North Carolina speaks highly of the vigorous preparedness efforts of the Raleigh office.

On the evening of November 27th, our forecasters in Kansas City were monitoring the weather over the nation and, in particular, the thunderstorm activity that was spread out over the southeastern states. Conventional weather observations plus satellite and radar data did not suggest that severe weather was likely even though thunderstorm activity was going on and was expected to go on. The fact that no severe weather had been reported in association with these thunderstorms during the normally more favorable late afternoon and evening hours added support to that belief.

Even with the luxury of hindsight and sifting through reams of data at a comfortable pace not available to the forecaster in the heat of battle, it is difficult to find clues that would have allowed us to say an hour or more in advance that there was a likelihood for tornado development in North Carolina.

While a thunderstorm is necessary for tornado development, we notice that less than one percent of all thunderstorms will spawn a tornado. That is, we have on the average maybe 100,000 thunderstorms a year in the United States and maybe only 1000 or less will generate a tornado. We are aware of certain conditions that favor tornado development, aware of the parameters that are favorable, but at times no tornadoes form in what appears to be a very favorable environment and on the other hand sometimes tornadoes will form in cases where the environment seems unfavorable.

The skill in weather forecasting depends to a large extent on our ability to observe and measure present weather conditions and to understand the physical processes involved. That is to say, a good diagnosis is necessary for a good prognosis. When it comes to observing and understanding tornadoes, we are faced with many deficiencies.

For example, tornadoes occur on such a small scale, they are difficult to observe. Their widths are normally measured in terms of yards and the parent thunderstorms from which they form may be only five to ten miles across. And that is far below the scale that we measure routinely at the National Weather Service, the weather that is ongoing.

For example, in the upper atmosphere, we look at reports that are maybe 250 miles apart. In this part of the country that would be like from Cape Hatteras, Greensboro, North Carolina and Charleston, South Carolina. So we are hampered by the fact that we just really sample what is going on in the atmosphere as opposed to getting a detailed diagnosis of what is happening.

Radar is an important took, as was mentioned before, and the NEXRAD shows a great deal of promise. You have in my prepared testimony the information on how we feel about some of the newer technology that is coming on line and how it is going to help. The geostationary satellites, the GOES-NEXT program, the automated surface observation program, upgrades tot he computer facilities, the AWIPS program that was mentioned before. All these things will be very helpful.

Another important part of that is the research that goes on to improve our understanding of the atmosphere, and Project Storm, that is being conducted by the National Science Foundation is going to help us understand the mechanisms and the development of small scale storms.

So in summary, the information available to us at the National Severe Storms Forecast Center did not suggest the potential for storms over North Carolina to intensify so dramatically. And that can be directly attributed to our present technology limitations and also another important aspect is our need for improved understanding of severe storm dynamics. It is not just a matter of new technology, although that is very important obviously.

So the Weather Service really stands poised now, looking to the future, on the threshold of a new frontier where improved technology should enhance not only our ability to detect severe weather, but to more accurately predict future development of severe weather.

Thank you.

[The prepared statement of Mr. Ostby follows:]

# TESTIMONY OF

FREDERICK P. OSTBY
DIRECTOR, NATIONAL SEVERE STORMS FORECAST CENTER
NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

BEFORE THE

SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE
RESEARCH AND ENVIRONMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

MARCH 3, 1989

Mr. Chairman and Members of the Subcommittee:

The Raleigh tornado was a rare event considering the geographical area, the time of day, and its extreme intensity. Prior to this episode, records dating to 1916 indicate that there has never been a November killer tornado in the State of North Carolina. Furthermore, records show that there have only been three tornadoes in November, nationwide, during the past 35 years that were as intense as the Raleigh tornado. Neither a watch nor a warning was issued before the tornado struck. This was due in large part to our present limited ability to sample the atmosphere in three dimensions and to take the pulse of rapidly developing small scale (mesoscale) storm systems.

Tornado and severe thunderstorm watches are issued by the National Severe Storm Forecast Center in Kansas City and are intended to alert the public as to the potential for development of severe weather. Tornado and severe thunderstorm warnings are issued by field offices, such as the Raleigh Forecast Office.

Warnings demand immediate response actions as they signal that severe weather is either occurring of is imminent.

Another facet of the Weather Service warning program is our warning preparedness and coordination efforts that attempt to ensure that local decision makers and the general public understand the watch and warning information available to them and how to take necessary safety precautions when severe weather threatens. The miraculously low death toll in North Carolina speaks highly of the vigorous preparedness efforts of the Raleigh office.

On the evening of November 27th, forecasters at the National Severe Storms Forecast Center were monitoring the weather over the Nation and, in particular, the thunderstorm activity spread out over the southeastern United States. Conventional weather observations plus satellite and radar data did not suggest that severe weather development was likely. The fact that no severe weather had been reported in association with these thunderstorms during the normally more favorable late afternoon and evening hours added support to this belief.

Even with hindsight, sifting through reams of data at a comfortable pace not available to a forecaster on the firing line, it is difficult to find clues that would have allowed us to say an hour or more in advance that there was a likelihood for tornado development in North Carolina.

While a thunderstorm is necessary for tornado development, less than 1 percent of all thunderstorms spawn a tornado. Though we are aware of certain conditions that favor tornado development, occasionally either no tornadoes form in what appears to be conducive conditions, or tornadoes do occur in apparently unfavorable conditions.

Skill in weather forecasting depends to a large extent on our ability to observe and measure present weather conditions and to understand the physical processes involved. That is, a good diagnosis is needed for a good prognosis. When it comes to observing and understanding tornadoes, we are faced with many deficiencies.

Because tornadoes occur on such a small scale, they are difficult to observe. Their widths are normally measured in terms of yards and the parent thunderstorms from which they descend are generally no more than 5 to 10 miles across. This is far below the scale that the National Weather Service acquires most of its observational data.

Small fluctuations in upper atmospheric flow patterns are also extremely important in the detection and forecast process. Unfortunately, upper-air soundings to measure such changes are taken only every 12 hours by balloon-borne instrument packages launched from widely spaced locations. For example, in the area around the Carolinas, we only have reports from Cape Hatteras, Greensboro, and Charleston -- about 250 miles apart from each other.

Radar is an important tool in severe weather forecasting because it can fill in some of the gaps in our observing system. While present day radars do an adequate job in detecting precipitation, they cannot measure wind speeds. Our next generation radar (NEXRAD) will have the capability of determining storm scale wind speeds using Doppler based technology.

Imagery from geostationary satellites also helps in making up for some of the limitations of our observational systems. On the night in question, there was no hard evidence of more than moderate to strong thunderstorms. An improved next generation satellite (GOES-NEXT) is scheduled to be launched sometime in 1990. One of its features will be a much improved image resolution which will enable us to identify finer scale cloud features.

During the early 1990's, the Weather Service intends to further fill some of the observation gaps by introducing automated surface observation stations (ASOS) across the country. A new upper air wind profiling system will also be installed, mainly over the central United States. Both of these systems will be able to report on a nearly continuous basis.

Currently, we are planning to enhance computing power at the NOAA computer facility. Planned upgrades will lead to more accurate and more specific forecasts of major storms. Similarly, we are in the definition phase for our Advanced Weather Information and Processing System (AWIPS) which, when implemented, will integrate and assimilate all meteorological and hydrological data at our field offices. This system will provide fast-response, interactive analysis and display of the data to support our meteorologists in rapid decision making, warning preparation, and product dissemination.

Finally, research is underway to improve our understanding of the atmosphere at all scales and in the formulation of more rigorous numerical models. Project STORM is being conducted by the National Science Foundation to help understand the mechanisms involved in the development of small-scale storms.

In conclusion, information available to the National Severe Storms Forecast Center did not suggest the potential for the storms over North Carolina to intensify so dramatically. This can be directly attributed to our present technology limitations and our need for improved understanding of severe storm dynamics. However, the Weather Service stands poised on the brink of a new frontier where improved technology should enhance not only our ability to detect severe weather but to more accurately predict future development of severe weather.

Mr. **Price**. Thank you. I would like to begin by complimenting the National Weather Service for the successful emergency preparedness and public information program that you have put into place. It has been referred to several times this morning as one of the real success stories of this experience. That effort was implemented after the hearings that Congressman Valentine held in 1984, and I do not think there is any question at all that it saved perhaps hundreds of lives, at least dozens of lives during this latest disaster, so we compliment you for that and of course want to work with you to continue and strengthen that program.

I hope it is also clear here this morning that we are here in a supportive mode. We understand the funding shortages, the personnel shortages, the technology shortages that your agency has labored under and we hold these hearings not with the intention of blaming anyone but with the intention of asking the hard questions about what those shortages, shortfalls, have produced in the way of reduced forecasting capability. We intend to develop our understanding, develop the Committee's understanding of what the needs of the Weather Service are going to be in order to ensure that stations like Raleigh-Durham will be equipped adequately in the future and that this kind of forecasting capability is going to be there when we need it.

We are very, very alarmed at what has happened and at the evidence that this in-house report gives us that there are serious problems that have prevented our using fully even the technological capability that we now have. There is a lot of evidence of National Weather Service reliance on outdated technology, and you have said that yourselves in your own statements.

You indicated that our current technological capabilities did not enable us, even if they had been fully operative, did not enable us to detect and predict this tornado, to give any warning whatsoever.

Now you are not saying that the technology does not exist to give some warning. The technology is under development. You are simply saying that we do not have it, is that correct?

Mr. **McPherson**. That is correct essentially, yes, Congressman Price.

Mr. **Price**. Now you mentioned the current effort to implement NEXRAD, the next generation Doppler radar. How many years has that program been going on?

Mr. **McPherson**. The program I think has been underway about ten years and the first operational unit will roll off the line in January of next year.

Mr. **Price**. Why has it taken that long to get this system operational and especially to get it located at critical stations like our own?

Mr. **McPherson**. Well first of all it is a very expensive system. We are talking—since it is, I am sure you are aware, a joint effort of the Department of Commerce, Department of Transportation and the Defense Department, each of which organization has its own interests and commitments that this program must satisfy. That means that that is a complicating factor in organizing the program. The program was organized, however, as a joint project in order to effect cost savings in what would otherwise be an even more, much more, expensive program.

Secondly, the development of a nationwide system that must serve operational needs of three different agencies is in itself a very complex proposition, technologically a very complex proposition. We do not wish to purchase expensive pieces of equipment that turn out to be very difficult to maintain or turn out to not do what we expect them to do. So it has been a very long process, but it has been a very thorough process, and when the radars do in fact become available, I am convinced that we will be very, very proud of these radars and they will serve us in good stead.

Mr. PRICE. Now the NEXRAD systems right now are located in how many locations, the experimental systems?

Mr. McPHERSON. Well we have one that is undergoing testing, it's a prototype version in Norman, Oklahoma.

Mr. PRICE. When do you anticipate that that prototype will be fully developed and ready for application elsewhere?

Mr. McPHERSON. It is undergoing testing right now. We expect the tests to end early this summer after the severe weather season in the Oklahoma area. Final refinements will be made during the summer and the fall and the first production version of NEXRAD will come off the line in January of next year.

Mr. PRICE. January of 1990?

Mr. McPHERSON. That is correct.

Mr. PRICE. And you anticipate that stations such as Raleigh-Durham could take advantage of this technology a couple of years later?

Mr. McPHERSON. The present schedule is for the radars to be delivered at approximately the rate of one every month and the Raleigh-Durham installation is scheduled for December of 1992.

Mr. PRICE. What determines that priority listing?

Mr. McPHERSON. There are a number of factors that go into those considerations, Congressman Price. One is, first of all, that the project involves three departments of the Executive Branch of the Government each, as I indicated, with different missions to accomplish.

The second factor has to do with the need. As has been noted previously in this hearing, the central part of the United States is in fact more tornado prone than are other parts. The eastern is somewhat less prone, the western portion of the United States has practically no tornado activity, so consequently the deployment schedule attempts to recognize that fact as well. Finally—

Mr. PRICE. What would it take to speed up that deployment schedule? Is it mainly a question of dollars?

Mr. McPHERSON. It is at least partly a question of dollars, but the procedure—once a radar set rolls off the production line, there has to be a facility ready to receive that radar set. The process of land acquisition, negotiations with landowners, the process of construction, is a very long, drawn out process. We allow a 40-month window prior to the delivery of equipment to begin the process of land acquisition and construction of a facility.

Mr. PRICE. The present facilities at Raleigh-Durham, which even to a casual observe appear cramped and crowded, will they require substantial modifications to accommodate this system or are you considering perhaps moving the facility altogether?

Mr. McPherson. Well the radar itself, the Raleigh-Durham radar itself will be located some distance south, about 20 miles I believe to the south of the Raleigh area. In general our policy is to try to do the most cost-effective—make the most cost-effective decisions with respect to new facilities. So far as I know, no absolute decision has been made as to whether or not to rehabilitate the present facilities at Raleigh-Durham or whether to build new ones.

Mr. Price. Mr. Muller, do you have any opinion as to how much of that 40-month window might be required to prepare our facilities?

Mr. Muller. I really do not know, I really have no feeling for that, Congressman.

Mr. Price. Let us get back to the question of dollars for a minute. Can you fill us in a bit on the history of this? My understanding is that OMB, the Office of Management and Budget, has been critical of this system, has in fact at various times recommended that it be deleted from the budget. It was last year, I think, that OMB tried to terminate the new automated weather interactive processing system, the AWIPS program. Is that true?

Mr. McPherson. Yes, that is true, that is correct, yes.

Mr. Price. So you have had to fight for even the appropriations that you have gotten to develop these systems.

Mr. McPherson. That is correct, yes.

Mr. Price. Why do you think OMB has been so hesitant to underwrite this program of development?

Mr. McPherson. My belief, and I will state it very carefully as my personal belief, is that there is a different view in the Office of Management and Budget as to the role that the National Weather Service should play in providing weather services in this country.

Mr. Price. Could you elaborate what the difference is?

Mr. McPherson. The OMB view is that the modernized National Weather Service should have far fewer stations than we currently operate. That is mostly a matter of budget as opposed to program, but that is their view.

Mr. Valentine. Mr. Chairman, could I break in here? Do they not also want to interject this business of privatization into the Weather Service?

Mr. McPherson. That is another part of the issue, yes, sir.

Mr. Valentine. I mean I do not want to lead you to say anything that would cause any problems, but I mean hasn't the past administration indicated that they want to sell the National Weather Service to some individuals after all that the taxpayers have put into it through the years?

Mr. McPherson. I plead, Congressman Valentine, that I was not party to those discussions. I had my job since October of last year. But I do not believe that there was ever an official position of the previous administration that offered or proposed selling of the National Weather Service. There has been a debate, a very legitimate debate in my view, about the role of the National Weather Service, the public sector of meteorology as opposed to the private sector of meteorology. And that debate is continuing.

Mr. Price. Well, certainly one way to bias that debate is to close down 130 stations and to prevent the agency from developing and utilizing state-of-the-art technology. You may not say it in so many words, but that is the net effect, is it not, to make the Weather Service look bad and create a climate where privatization begins to appear to be a serious possibility?

Mr. McPherson. I suppose that is possible. With respect to the plans for modernization of the Weather Service, we believe that we can indeed, given the new technology available to our offices, we believe that we can deliver a higher level of services with a smaller number of stations. That is a view by the National Weather Service that I can defend as a professional meteorologist, down to a point. There is, however, a point below which the number of National Weather Service offices serving the United States would be too small for me to be willing to defend as a professional meteorologist.

Mr. Price. Well, the evidence from November 28 suggests that the Weather Service offices on the periphery of the Raleigh-Durham area did not provide the kind of warning we could have wished for. If you thin that network out further, it could hardly increase that capability, could it, particularly if the technological upgrading does not move ahead?

Mr. McPherson. Well, certainly if the technological upgrading does not move ahead, then we are indeed in the position that you indicated, but as I said, with the acquisition of the new technology we believe that we can provide a high level—a higher level of service than we are doing now with a smaller number of stations.

Mr. Price. Mr. Valentine. I will have some more questions, but I would like to recognize my colleague.

Mr. Valentine. I just have one or two, Mr. Chairman.

The NEXRAD development which you described, Dr. McPherson, as being scheduled for installation I think at Raleigh-Durham in December 1992, could you tell us about how far along that is on the installation schedule? I mean is that—well let me ask it differently, how long is it going to take to get this new system installed everywhere that it needs to be installed in the United States?

Mr. McPherson. We anticipate completion of the installations in the United States by the end of calendar year 1995. So the installation in the Raleigh-Durham area is about in the middle of that process.

Mr. Valentine. The problems that have been pointed out by reports that are before you and analyses of the situation and how different organizations and arms of government functioned during this tragic period—I want to talk a little bit more about the radar systems and the failed radars in the State of North Carolina. What about the Cap Hatteras network radar, the situation I understand that there was some malfunctioning in that operation? Can you tell us something about what type of equipment is involved? Cape Hatteras is very important, I should think, to the Weather Service as a place from which to glean information which would be of service, much more important than its geographic isolation would indicate. Can you talk to us some about that?

Mr. Muller. Both Cape Hatteras and Wilmington, North Carolina are coastal radar stations. They are staffed with a staff of meteorological technicians who monitor a 1957 radar in the 10 centimeter wave length called the WSR-57 radar. That radar has had many modifications. Being 1957, it still is tube type equipment, not solid state as the current generation of electronic products are. It has been modified to a great degree, there are no longer parts available from the manufacturer. Parts that are on order for that type of radar—it is not like a television set, if something goes bad you have a stock of tubes in the local hardware store, you must have a depot to order parts from. The parts that come in may have not been changed or used in 10 or 15 years. Putting those into that radar, then they do not solve the problem, they may have just deteriorated from age. So the electronics technicians who work very desperate to keep that equipment up have provided maintenance and modifications to some of this to keep those radars in operating condition.

At Cape Hatteras where we are very subject to the elements, salt spray causes deterioration of radar towers, we have electrical outages that occur from salt spray that accumulates on the cables. It causes a very severe problem for us, so Cape Hatteras does go out quite frequently.

Have I addressed your question?

Mr. VALENTINE. Yes. Surely Hatteras would be on the list for early installation of NEXRAD.

Mr. MULLER. The location, as Dr. McPherson has indicated, a lot of these radars will be relocated to provide more of a strategic covering using that 115 base line stations and the Cape Hatteras radar is tentatively planned to move to the Morehead City area.

Mr. VALENTINE. Is that because it would be easier to service or is that a better area geographically, or because of the atmosphere or the other reasons?

Mr. MULLER. Yes, there are two reasons. One, there would be a network radar also installed in southeastern Virginia, the new Doppler radar is planned to be located in the southeastern Virginia area which would also cover northeastern North Carolina with Doppler image. Therefore the duplication of radar with Virginia and Cape Hatteras both covering the same area would be a better location to move that radar further south.

Mr. VALENTINE. Is there no special advantage to having the radar out as close as you can get to that protrusion out into the Atlantic?

Mr. MULLER. Well possibly, but the position of Cape Hatteras radar was initially put there because it went as far out into the ocean as we could get. But this was done in 1957 prior to the installation of orbital satellites and geostationary satellites. These satellites give us much better indications on hurricane locations, but the original location of the Cape Hatteras radar was to cover the area to provide better coverage of hurricane imagery. But now that we have satellite coverage, it is more important to get the hurricane coverage as the storm gets closer into the coast, yet it will not be completely knocked out by a hurricane.

At Cape Hatteras my fear is that a major hurricane will someday come through the Cape Hatteras area and knock that station out, thereby destroying our abilities to even measure the winds or the facilities around that isolated area.

Mr. VALENTINE. Was there any unusual problem in connection with that downtime of the radar at the Raleigh-Durham Airport, was there any special problem that delayed the repair efforts?

Mr. MULLER. Yes, we had ordered a part for that radar on Sunday when the radar first went out on November 20, we called a maintenance man in on an overtime basis because at that time we did have weather that we were concerned about. He placed an emergency order for a part, the part was shipped from our logistics center on Sunday. We received the part Monday, but when the part came in, that entire piece of equipment had been modified and that part would no longer even fit in the radar. It had to have a modification kit, which was then sent the following day. That modification was then made to it, but that still did not work because the part that was shipped, the PFM, had apparently either gone bad from age or had not been quality controlled by the contractor who was working with it, therefore, as of Wednesday evening we still had no equipment to repair the radar.

Mr. VALENTINE. Has there been any indication or do you or any other people who are charged with responsibility in this general area have any suggestion to make with respect to whether or not the inadequacies that existed, if any, in connection with the performance of duties of various governmental agencies, had anything to do with the lack of personnel, does anybody make that claim that you did not do something that you might have done if you had more people to do it?

Mr. MULLER. At the Wilmington station, the cutback of staffing at Wilmington has reduced our coverage to one man on duty from midnight to eight o'clock in the morning. During a severe weather situation, the person on duty can authorize another weather observer to come onto location on an overtime basis. At Wilmington we had two people who were on annual leave at that time, on vacation and not available for recall, and one person had submitted a sudden resignation, leaving the station very short-handed. The meteorological technician at Wilmington, knowing that his staff was so short-handed, declined not to call somebody in on an overtime basis but decided that he could weather out the storm by him watching the radar, getting his contacts out and handling the other duties with just one man handling it.

Mr. PRICE. Excuse me, Mr. Valentine.

Mr. VALENTINE. Sure.

Mr. PRICE. Do you think the awareness by personnel of the budget constraints, the budget problems, does that create inordinate pressure in situations like this?

Mr. MULLER. I think it does, yes. I think it would be foolish to say that it would not, knowing that we are bound by a constriction of budget that everybody who is involved with things that are employed by the federal government are very concerned with the possibilities of saving money.

Mr. VALENTINE. Do any of you have any estimate that you could have with us as to the total cost to the taxpayers in this country of the new NEXRAD radar system? Let me put it this way, over and above the cost of maintaining the outdated equipment which we now have. In other words, what is going to be the net cost to the American taxpayers of doing what we need to do in this area?

Mr. MCPHERSON. Well I think the NEXRAD program—I do not have the figures directly at my disposal, Congressman Valentine, but my recollection is that the NEXRAD program by itself is fairly close to half a billion dollars.

Mr. VALENTINE. Half a billion?

Mr. MCPHERSON. Half a billion dollars.

Mr. VALENTINE. And we are talking about new money, additional money from the taxpayers in this country if the job which, you know, everybody agrees has to be done is done.

Mr. MCPHERSON. That is new money, yes, sir.

Mr. VALENTINE. You would not care to comment on how that jibes with politicians who say no new revenue, read my lips?

[Laughter.]

Mr. MCPHERSON. You are correct, Congressman Valentine, I would not like to comment on that.

[Laughter.]

Mr. VALENTINE. Well you know, I just—some people seem to think we can have all the things that we need to have to maintain a great nation, that we can protect our citizens, that we can protect tornadoes henceforth—we can predict them and that we can do all that without spending money. If we have things, it is going to cost somebody to get it one way or the other, by borrowing or otherwise.

Yes, sir?

Mr. MULLER. I would like to comment one thing, I do not want to leave you with the wrong impression that we are not going to use overtime when lives are at stake. I think any time we know there is a severe weather situation, if there is a severe weather watch, if the forecasters are anticipating severe weather, we will not hesitate to call people in on an overtime basis. The last snow storm that we had last week here in the Raleigh area, I worked a 14-hour shift. We are not reluctant to call people in to handle these situations, and that is what every meteorologist who works for the Weather Service has been firmly ingrained in. There is no way that you ever concern yourself with additional people when you have public lives at stake.

I wanted to clarify that point. If the person on duty at Wilmington was not thinking in terms of severe weather occurring, then he might say well I do not anticipate severe weather, therefore I can weather this situation out without costing the government any additional money. But in a severe weather situation, if we had known the elements were such that tornadoes could develop or if we knew that the weather was such that a hurricane was threatening, no one is going to concern themselves with an amount of money being saved on overtime because we do not put the public of this country in jeopardy by not using overtime. I wanted to just clarify that one point.

Mr. VALENTINE. Thank you, sir.

One statement and I will be finished. Mr. Ostby, our Transportation, Aviation and Materials Subcommittee will be in Congressman Glickman's district in Wichita sometime within the next several months for a field hearing and I hope to see you there.

Mr. OSTBY. Very good.

Mr. VALENTINE. Thank all of you.

Mr. PRICE. Let us get back to the budget discussion for just a moment. We have this NEXRAD system under development, we have this computer system under development, the so-called

AWIPS system. Is the need for this new technology, the need for this development program in your view adequately reflected in the President's 1990 budget proposal?

Mr. McPHERSON. It is adequately reflected as a start. Additional funds, I am bound to say, will be required in the out-years, but it is adequately reflected as a start on these items, especially the items involving the AWIPS system.

Mr. PRICE. How do your initial requests for funds on these programs compare with OMB's final recommendation?

Mr. McPHERSON. OMB's final recommendation is generally a good deal less, sir.

Mr. PRICE. Can you be a little more specific?

Mr. McPHERSON. The process is a very complicated one, as I am sure you are aware. It is a process which involves a great deal of negotiation amongst members of the people from the Department of Commerce and OMB. It is a process which involves a good deal of tradeoffs on various programs. It also has to recognize the very serious budget deficit that we have in the country at this time. We in the National Weather Service submit budget requests that reflect, to the best of our ability, the requirement, the need that is there. Others that are concerned with the budget have a different view of that.

Mr. PRICE. Well, clearly they do. And we have a history in this administration not just of recommending minimal funding but actually wanting to terminate the program. So you understand the suspicion that whatever comes out of the pipeline, the administration's budget does not come anywhere close to meeting the needs in this area. Certainly our need in a critical area such as this is for the earliest deployment of this technology.

Mr. McPHERSON. I would say, Congressman Price, that in my judgment the funding of the capital programs, the NEXRAD, the AWIPS, the new computer systems, does not include as much money as we would like. The largest difficulty though I think has to do with budget shortfalls in the immediate years, fiscal 1989 and fiscal 1990, have to do with the operating budget of the National Weather Service as opposed to the capital budget.

Mr. PRICE. You say the greater problems have to do with that?

Mr. McPHERSON. I believe so, yes.

Mr. PRICE. Could you elaborate?

Mr. McPHERSON. The budget shortfall, if one takes the FY 1989 and 1990 budgets together, the shortfall in the National Weather Service operating budget is in the vicinity of $45 million. That will be very difficult to come to grips with.

Mr. PRICE. That shortfall is computed from what base line?

Mr. McPHERSON. Computed from fiscal 1988.

Mr. PRICE. What it would take to maintain fiscal 1988 operations?

Mr. McPHERSON. That is correct.

Mr. PRICE. Short of that by $45 million?

Mr. McPHERSON. That is correct.

Mr. PRICE. Well in the administration's proposal, how is that saving to be realized? Does that mainly reflect the closing of these 130 stations?

Mr. McPHERSON. Well the negotiations are still going on within the Department of Commerce as to how that is going to happen. It may well be that some reprogramming will have to be forwarded to the Congress, a reprogramming request will have to be forwarded to the Congress. Certainly a portion of that shortfall will have to be absorbed by the National Weather Service operations, and that may well mean that we will have to reduce hours at the very least at some of our stations, especially some of the smaller stations across the country.

Mr. PRICE. In other words, the kind of personnel shortages, the kind of delays in repairing equipment that we saw all too well on November 28 might actually become more common?

Mr. McPHERSON. I believe so, yes, sir.

Mr. PRICE. Well the NOAA authorization bill that was signed into law last year directed the Secretary of Commerce to release the National Weather Service's ten-year strategic plan to modernize equipment, upgrade operations. The law specified that that report was to be sent to Congress within 90 days after enactment of the law, which was on February 17, yet that plan has not yet been released. Why is that?

Mr. McPHERSON. I am as chagrined about that as you are, Congressman Price. The only thing that I can tell you is that as of last night when I talked to Dr. Friday by telephone, the plan is still undergoing fine-tuning within the Executive Branch of the government and I cannot give you an estimate as to when that plan will be released.

Mr. PRICE. So the 90-day deadline apparently meant very little.

Mr. McPHERSON. It meant a great deal to me, sir.

Mr. PRICE. But to those who were immediately responsible for producing the report. Do you have any explanation, Mr. Ostby? Any of you have any—

Mr. OSTBY. No, I do not.

Mr. McPHERSON. The process by which the plan finds its way to the Congress, sir, it must be transmitted to the Congress by the Secretary of Commerce and it must have the approval of the Office of Management and Budget before that is done.

Mr. PRICE. Has that report been forwarded to OMB as far as you know?

Mr. McPHERSON. It has indeed, yes, sir.

Mr. PRICE. How long has OMB been looking at it, so to speak?

Mr. McPHERSON. Since about the middle of January.

Mr. PRICE. So it was very recently forwarded to OMB, six weeks ago?

Mr. McPHERSON. Yes, that is correct.

Mr. PRICE. I have an additional question dealing with the technology used for the NOAA weather radio system. I understand you are currently using a 20-year-old tape cartridge system to disseminate severe weather warnings over the NOAA weather radio system. Mr. Muller was kind enough to demonstrate that equipment to me a few days ago. This system is being used in spite of the fact that an advanced solid state audio system was developed in North Carolina, as a matter of fact, at NOAA's request, to replace that obsolete technology.

Can you tell us why the National Weather Service has not implemented this new technology which would, I understand, speed up the dissemination of severe weather warnings?

Mr. McPHERSON. Yes, sir, there are two reasons for that. One is a question of money. The second is a question of how best to implement such technology. There is a thought that perhaps the best way to implement new technology of that sort would be in connection with the advanced weather information processing system, the AWIPS system which has been referred to earlier. Studies are going on now to determine what would be the most cost-effective way of accomplishing that. The question really boils down to whether we produce and implement and interim upgraded NOAA weather radio system or whether we integrate that updated NOAA weather radio system into the AWIPS. And that debate has not been decided yet.

Mr. PRICE. When is it likely to be decided?

Mr. McPHERSON. I would guess that the decision will have to be made before the end of this summer.

Mr. PRICE. Let me get back for just a minute to the circumstances of November 28. There seems to be no question that this is a storm that came up suddenly, that many of the early warning signals were not there. On the other hand, the same cold front that passed through North Carolina that night had already caused severe weather, had it not, including tornadoes in Oklahoma and Texas and Louisiana and Mississippi, Alabama and Arkansas? Is that true, and if it is, why would not that earlier weather pattern have made it possible for you to increase the level of your alert here?

Mr. OSTBY. That is correct, there was earlier severe weather, as you mentioned, on previous days, on Friday and on Saturday, through those areas, mainly late afternoon and early evening. But then on Sunday, the day in question, the night in question, that afternoon or evening, there was absolutely no severe weather occurring at all. So it seemed as though the mechanisms to produce the severe weather which had been going on for the previous two days had relented or had absented themselves so that it seemed to be a different kind of system, weakening system, from a severe weather standpoint, not a weakening system as far as thunderstorms and heavy rain were concerned. That was definitely in the picture, but as far as severe weather was concerned, it seemed as though that had abated because in the late afternoon or evening, there was none going on at all on that Sunday even though there had been some on Saturday and Friday, which we had anticipated in the forecast.

Mr. PRICE. Are all of you in agreement, then, that even if the Raleigh-Durham system had been fully operative, there probably would not have been a warning issued? Of course, that is partly a question of how quickly the weather system developed. It is also a question of how serious the ground clutter problem—referred to earlier—is, in your judgment.

Mr. OSTBY. I agree with that assessment, yes. In fact, going back to the problems of the older kind of radars that we deal with, around the country for the most part, the bulk of our warnings that are issued for tornadoes are almost after-the-fact. That is, they are based on a report from a spotter that there has been a touchdown occurring and so many of the warnings are on the basis of spotter report or something of that sort. Very rarely does the current kind of radar, the 1957 technology that Mr. Muller was talking about, seldom does that indicate a very good signature to give you the confidence that that particular storm may be producing a tornado.

Mr. MULLER. A tornado warning by definition means that a tornado has been reported or a tornado is imminent. If we have a spotter, a police officer who actually sees a tornado funnel, that person can contact his radio center, they in turn can pass the message directly to us through the NAWAS phone system. Our person having a good reliable report of a tornado from a spotter, if he has a lot of confidence in that report, can immediately issue a warning. If the situation is unlikely for that kind of report, then he probably will do a little bit of looking to make certain that he has some other indications of it, i.e., verifying it on radar.

A tornado watch, on the other hand, implies that meteorological conditions are such in a prescribed area during a prescribed time that severe weather, tornadoes or severe thunderstorms can occur. If the forecaster at any office, or the person operating the radar at any office, sees a very clearly defined tornado signature, whether there is a tornado watch in effect or not, will probably issue a tornado warning on the basis of that signature. But as Mr. Ostby has said, that occurs very infrequently.

If a tornado watch or severe thunderstorm—if a tornado watch or severe thunderstorm watch is in effect, the person operating the radar, if he picks up a very strong radar echo, can logically assume that meteorological conditions are such that severe weather may occur, will not jeopardize the public, but will go ahead and issue the warning knowing that these conditions are possible to occur. I have the potential as a strong storm, I would rather issue a false alarm maybe one time out of six than I would not not let this go by without a warning.

Mr. PRICE. How serious is this ground clutter problem that most witnesses have referred to? When you talk about radar being rendered useless or less useful over an area as broad as virtually the entire Triangle area, including much of these three cities—is there something to Mr. Caplan's earlier suggestion that perhaps a different location, given the growth that we have experienced around the airport, might be advisable in the future?

Mr. MULLER. I do not believe the problem is as great as that. I think when you saw the radar in our office, there was a five-mile circle encompassing our area, which is totally blacked out. The reason for that is—

Mr. PRICE. A five-mile circle, five miles in radius?

Mr. MULLER. That nothing can appear, that is just a five-mile circle that is totally black. That is to stop the tube from burning out because of the intensity of the echo return within that circle. Then in addition to that, there is about a 25-mile area of which there will be buildings and reflectivity of the earth itself in which you will have a very difficult time picking up signature.

Mr. PRICE. Twenty-five mile radius or diameter?

Mr. MULLER. Twenty-five mile radius.

Mr. PRICE. Radius.

Mr. MULLER. Our radar scans horizontally, it's the normal scan rake. As Greg Fishel pointed out, you can stop the radar and scan vertically, but you can never scan something that is almost overhead because the antenna cannot direct straight up. Doppler radar, on the other hand, the NEXRAD system, is designed to scan both horizontally and vertically in an entire sweep. So the Doppler radar would give the forecaster a three-dimensional presentation as opposed to seeing a one-dimensional presentation of what he is seeing in the reflectivity mode. In addition, it would be able to give you wind circulation that may occur prior to the actual touch-down of a tornado. In short, with a Doppler radar, you are seeing many more signatures that can occur that can indicate both the down burst associated with severe thunderstorms and the mesocirculation that can develop with a tornado.

Mr. PRICE. We need to move on to our last panel, but I must say that I do not find the things you have said this morning as reassuring as I would like. I feel that under the circumstances, the Weather Service's performance on November 28 was very strong in many respects. But when we hear you testifying about the kind of difficulties you have within the administration, within the budget process; when we know that the state-of-the-art technology is under development, but yet we know it is going to take us years to have that placed here; when we hear administration officials talking about privatization of the entire operation—knocking out whole systems, you know, it is not reassuring. It underscores for me the assumption that we made in convening this hearing, that indeed the problems of November 28 do point to deeper problems.

I very much hope that as we move into the authorization process for the Weather Service for the next few years, that the Subcommittee and the Science Committee can take a searching look at these problems.

Will you send us your recommendations on specific provisions that should be included in that authorization legislation?

Mr. MCPHERSON. We will certainly work with the Congress in making those recommendations known, yes, sir.

Mr. PRICE. Thank you. Mr. Valentine.

Mr. VALENTINE. Just one final question. Mr. Muller, can you tell us what percentage of the time that the National Weather Service is able to predict these tornadoes that do develop?

Mr. MULLER. Our office in Raleigh maintains two statistical figures; one, the probability of detection, which is whenever a severe weather occurs, takes place in the state, we determine whether or not a tornado warning preceded it. Our accuracy on that is about 50%. The second figure that we use is a false alarm ratio, which measures how many times we have issued tornado watches and how many times those tornado watches have—or warnings rather, I am sorry—how many times we have issued tornado warnings and those warnings have not been followed by a severe event. If the number of warnings is so great that the public loses confidence in us, then we have an apathetic response. So our accuracy or our false alarm ratio is about 40%, which means that 40% of our warnings do not have severe weather events following them, but 60% of our severe weather warnings usually have a severe weather occurrence following the issuance of the warning.

Mr. Valentine. Thank you, sir.

Mr. Price. Thank you gentlemen very much.

We will call our last panel and thank these gentlemen for their patience. Our fourth panel consists of professors of meteorology, experts in the field; Dr. Charles Anderson of North Carolina State University and Dr. Edward Brotak of the University of North Carolina at Asheville. We appreciate you being here and we will follow the same procedure with you that we did with earlier witnesses, asking you to summarize your statement, realizing that the statement in full will be inserted for the permanent hearing record.

Dr. Anderson, we would appreciate you going first.

## STATEMENTS OF DR. CHARLES E. ANDERSON, NORTH CAROLINA STATE UNIVERSITY, RALEIGH, NORTH CAROLINA and DR. EDWARD A. BROTAK, UNIVERSITY OF NORTH CAROLINA AT ASHEVILLE, NORTH CAROLINA

Dr. Anderson. Good morning, Mr. Chairman and members of your Subcommittee. I have been working with severe storms and tornadoes for the past ten years, both as a member of the faculty at the University of Wisconsin in Madison and now here at NC State.

We have been studying the November 28th tornado in my Severe Storms Group at NC State since it occurred and we have reached a number of very interesting ideas about what took place, which will have some bearing on the warnings issue as well as on the tornado watch issue.

I am pleased to have this opportunity to present my views on these subjects and I hope they may have some influence on the operational responsibilities of the National Weather Service.

I think we are all aware that tornadic phenomena probably represents the least meteorologically understood phenomena that we have in the field. We do not know how these things come into being, we do not know how long they will last, we do not know how to distinguish ahead of time which is going to be a very severe storm versus one which is going to be fairly harmless. So it should be clear at the outset that the responsibility of the National Weather Service which uses current technology for the forecast, the watch and the warning, is based more on art than it is on science. And I would think everyone would agree that as our basic understanding improves, of the meteorology and physics involved, then we should do a better job in the area of forecasting, detection and warning.

We believe that the watches provided by the National Severe Storms Forecasting Center in Kansas City could be improved by including in the currently used subjective composite techniques more objective techniques based on statistical regression analyses. My own group has demonstrated that many historical severe storm and tornado outbreaks could be explained with the use of two very essential measurements in the pre-storm environment. The potential buoyant energy or PBE and the 0-4 kilometer mean wind shear. Our own regression analyses has shown very encouraging results to date.

Let me caution that these results are not forecasts but are attempts to show the relationships between the type of severe storms outbreak which occurred in the past and certain values of these two variables. We also know that Kansas City has conducted some limited experiments with these two parameters which yielded mixed results.

I would strongly urge that the National Severe Storms Forecast Center use regression analyses in its data to determine the value of the PBE and mean wind shear to the forecast problem instead of an index approach. We appreciate that the NWS would have to extensively test these suggested techniques before using them in an operational manner. However, the strength of this suggested approach lies in the evidence of the sensitivity of the behavior of simulated numerical models of severe storms to various input levels of PBE and mean wind shear. Many numerical modeling studies have shown the validity of the connection between the type of outbreak and the nature of the pre-storm environment, with special emphasis on these two parameters.

With regard to the very difficult task of providing tornado warnings with its attendant problem of tornado detection, we anticipate some genuine breakthroughs when local forecast centers are equipped with Doppler weather radars and have access to geosynchronous satellite imagery in the visible and infrared at one kilometer resolution.

My own research has convinced me that there is a strong suggestion that the rotating thunderstorms which produce tornadoes have characteristic signatures in the outflow plume patterns from their tops. I have concentrated my attention on how well satellite imagery of these outflow patterns account for the level of tornadic intensity that is associated with a particular thunderstorm cell. Again, using past events only, we show that we are able to account for up to 90 percent of the variation in tornadic intensity through analysis of these characteristic outflow patterns.

Our research to date has employed bivariate regression analyses among tornadic intensity response and two predictors, the strength of the outflow in the plume and the amount of departure of the direction of the plume from the wind at the plume level. I have appended a research paper which shows some early results of this approach and since that paper we have accumulated a number of additional cases including the November 28, 1988 Raleigh outbreak. These additional cases behaved much in the same manner as those reported in our first publication. We are now experimenting with four predictor variables and we have high expectations that we shall be able to consistently relate the behavior of a particular thunderstorm cell to its outflow plume behavior.

If these findings stand up with more cases, we envision the following scenario for a local weather station. When a tornado watch, both in area and time, is issued by Kansas City, the local station would commence scanning this area with its Doppler radar for evidence of mesocyclone presence and also would examine the signature characteristics of individual thunderstorm cell outflow plumes. These outflow plumes would show up on the satellite imagery.

Those cells which show tornadic potential in their plume behavior would receive closer monitoring by the Doppler radar. A warning would be issued when a threshold value for the mesocyclone shear was reached or exceeded. The rate and direction of movement of the thunderstorm would be monitored by the Doppler radar so that appropriate warnings could be issued to localities in the anticipated path. By using both the Doppler weather radar and the satellite imagery, the local weather station would have the ability to do the following:

1. Identify with up to one hour's lead time those cells which show a potential for producing tornadoes based on satellite imagery,
2. With the same lead time, make a determination of the severity of any tornadoes produced by a particular cell, again using satellite imagery.
3. Monitor the development of mesocyclone formation within a suspicious cell so that a "now cast" could be made of when, where and how severe emerging tornadoes might be, and
4. Issue the necessary and appropriate warnings to the public.

Field tests of the ability of Doppler radar to improve tornado warnings was demonstrated in the JDOP experiments carried out in Oklahoma in the last 1970s by NOAA. Average lead time to tornado occurrence was increased to about 20 minutes. It was the success of these tests that led to the decision by NOAA and the other interested government agencies to build and install the NEXRAD system.

Mr. PRICE. Excuse me. Could I interrupt you, Dr. Anderson? Did I understand you to say that those experiments were carried out in 1977?

Dr. ANDERSON. That is right, JDOP was carried out in the late 1970s, yes.

Mr. PRICE. And we still do not have that system developed and deployed ten years later.

Dr. ANDERSON. Well you heard Mr. McPherson explain why.

Mr. PRICE. I certainly did.

Dr. ANDERSON. I am suggesting that an even more accurate prediction or a "now cast" with a longer lead time up to one hour may be made with the use of combined Doppler radar and satellite imagery observations. If a NEXRAD radar is placed in the Raleigh area, an excellent opportunity will exist to explore the potential of this combination. At North Carolina State University, we have the remote McIDAS work station needed to acquire the satellite imagery and to perform the necessary analysis of the plume behavior. Therefore, the necessary and critical elements would be together to permit exploration of the scenario I have just described.

Again, I appreciate the opportunity to give input to this Committee, and we at North Carolina State University are more than willing to work with NOAA to improve the forecasting, detection and warning aspects of tornado prediction. Our research has been sponsored by NASA and the National Science Foundation.

Thank you.

[The prepared statement of Dr. Anderson follows:]

Statement of Testimony to the Subcommittee on Natural Resources, Agriculture Research and Environment of the Committee on Science, Space and Technology, U.S. House of Representatives, Washington, DC, prepared by Dr. Charles E. Anderson, North Carolina State University, Raleigh, NC, at the hearings of March 3, 1989, in Raleigh, NC.

Good morning Mr. Chairman and members of your Sub-committee. I am Dr. Charles E. Anderson, Professor of Meteorology, NCSU. My particular expertise is in the field of severe local storms and tornadoes, and I have spent the past 10 years researching various aspects of these phenomena as a member of the faculty at the University of Wisconsin - Madison, and now at NCSU.

I was invited to appear to discuss problems associated with tornado forecasting and warning, and new technologies and procedures to improve NWS prediction, detection and warning capabilities. I am pleased to have the opportunity to present my views on these subjects, and I hope they may have some influence on the operational responsibilities of the NWS. We should be well aware that tornadic phenomena represent one of the least understood fields in meteorology, despite their awesome power to bring death and destruction annually to our country. Thus, the tasks of forecasting and warning have to rely on a limited understanding of the behavior of these storms: how they come into being, their life cycles, what distinguishes an extremely violent storm from one which is relatively harmless, and other important consequences of their existence. It should be clear that the forecast and warning responsibility of the NWS has to use current technology and methodology which is more art than science; and hopefully, it will gradually improve as our basic understanding of the meteorology and physics of these storms advances.

I and my associates in the Severe Storms Group at NCSU can contribute to the forecast and warning of these storms by employing new understanding of storm behavior, coupled with new advances in technology. Let me expand on this statement. We believe that severe storm and tornado forecasts (normally issued as "watches" by the National Severe Storms Forecast Center (NSSFC) in Kansas City) could be improved by including in the currently used subjective "composite" techniques more "objective" techniques based on statistical regression analyses. Research by Waisman and Klemp (1982), Rasmussen and Wilhelmson (1983), Leftwich and Wu (1988) and my own group has demonstrated that many historical severe storm and tornado outbreaks could be explained by two (2) essential measurements of the pre-storm environment; the potential buoyant energy (PBE), and the 0-4 km mean wind shear. Our own regression analyses has shown very encouraging results to date. Let me caution that these results are not forecasts but are attempts to show the relationships between the type of severe storms outbreak which occurred in the past and certain values of the PBE and shear in the pre-storm environment. We know that NSSFC has conducted some limited experiments with Shear/Energy Index (SEI) which yielded mixed results. I strongly urge that NSSFC use regression analyses techniques on its data to determine the value of PBE and mean wind shear to the forecast problem instead of the Index approach. We appreciate that the NWS would have to extensively test these suggested techniques before using them in an operational manner. The strength of this suggested approach lies in the evidence of the sensitivity of the behavior of simulated numerical models of severe storms to various input levels of PBE and mean wind shear. Many numerical modelling studies have shown the validity of the connection between the type of outbreak and the nature of the pre-storm environment, with special emphasis on these two parameters.

With regard to the very difficult task of providing tornado warnings with its attendant problem of tornado detection, we anticipate some genuine breakthroughs when local forecast centers are equipped with Doppler weather radars and have access to geosynchronous satellite imagery in the visible and infrared at one (1) km resolution. My own research has convinced me that there is a strong suggestion that the rotating thunderstorms which produce the tornadoes have characteristic signatures in the outflow plume patterns from their tops. I have concentrated my attention on how well satellite imagery of these outflow patterns account for the level of tornadic intensity that is associated with a particular thunderstorm cell. Again, using past events only, we show that we are able to account for up to 90 percent of the variation in tornadic storm intensity through analyses of these characteristic outflow patterns. Our research, to date, has employed bivariate regression analyses among tornadic intensity response and two predictors: strength of the outflow in the plume and the amount of departure of the direction of the plume from the wind at the plume level. I have appended a research paper which shows some early results of this approach (Anderson and Schrab 1988). Since that paper, we have accumulated a number of additional cases including the November 28, 1988, Raleigh outbreak. These additional cases behaved much in the same manner as those reported in our first publication. We are now experimenting with four predictor variables, and we have high expectations that we shall be able to consistently relate the behavior of a particular thuderstorm cell to its outflow plume behavior.

If these findings stand up with more cases, we envision the following scenario for a local weather station: When a tornado watch (area and time duration) is issued by Kansas City, the local station would commence scanning this area with its Doppler weather radar for evidence of mesocyclone presence and, also, would examine the signature characteristics of individual thunderstorm cell outflow plumes. Those cells which show tornadic potential in their plume behavior would receive closer monitoring by the Doppler radar. A warning would be issued when a threshold value for the mesocyclone shear was reached or exceeded. The rate and direction of movement of the thunderstorm would be monitored by the Doppler radar so that appropriate warnings could be issued to localities in the anticipated path. By using both the Doppler weather radar and the satellite imagery, the local weather station would have the ability to do the following:

1) identify, with up to 1 hour's lead time, those cells which show a potential for producing tornadoes based on satellite imagery,
2) with the same lead time, make a determination of the severity of any tornadoes produced by a particular cell, again using satellite imagery,
3) monitor the development of mesocyclone formation within a suspicious cell so that a "now cast" could be made of when, where, and how severe, any emerging tornadoes might be,
4) issue the necessary and appropriate warnings to the public.

Field tests of the ability of Doppler weather to improve tornado warnings was demonstrated in the JDOP experiments carried out in Oklahoma in 1977-78 by NOAA. Average lead time to tornado occurrence was increased to about 20 minutes. The success of these tests led to the decision by NOAA and other interested government agencies to install the Nexrad system. I am suggesting that an even more accurate prediction or "now cast" with a longer lead time up to 1 hour may be made with the use of combined Doppler radar and satellite imagery observations. If a Nexrad radar is placed in the Raleigh area, an excellent opportunity will exist to explore the potential of this combination. At NCSU, we have the remote McIDAS work station needed to acquire the satellite imagery and to perform the necessary analyses of the plume behavior. Therefore, the necessary and critical elements would be together to permit exploration of the scenario I have just described.

Again, I appreciate the opportunity to give input to this committee, and we at NCSU are more than willing to work with NOAA to improve the forecasting, detection and warning aspect of tornado prediction. Our research has been sponsored by NASA and NSF.

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# THE USE OF SATELLITE IMAGERY TO IDENTIFY TORNADIC THUNDERSTORMS

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## 1. INTRODUCTION

In recent years, Doppler radar has been used to demonstrate the connection between mesocyclones within thunderstorms and their tornadic potential. Scientists at NSSL have developed techniques which are capable of identifying specific Doppler signatures belonging to tornado producing mesocyclones. This work promises to increase the ability of the weather services to inform the public of the location, strength, and direction of movement of a tornadic storm. The Doppler radar is capable of detecting the presence of tornadic conditions before the actual funnel cloud has been spotted by ground observers and thus provides useful information about tornadic conditions in the time period between the issuance of a tornado watch by NSSFC and the tornado warning which is made after a funnel cloud has been observed. Unfortunately, Doppler radar coverage will be limited in areal extent because of the limited range of the radar beam and the limited number of Doppler radar sets placed in the field.

We have been experimenting with the possibility of identifying potential tornadic thunderstorms using characteristic signatures produced by the anvil emerging from a thunderstorm cell. Our goal is to parallel the Doppler radar developments and assist in the important task of alerting the public about dangerous severe local storms. If successful, we envision an operational arrangement in which the satellite image of a watch area is closely monitored to detect any potential tornadic cells; in turn, the position and movement of such cells would be passed on to the closest Doppler radar for more minute inspection and monitoring. In those instances where Doppler radar is not available, the information would be passed on to the nearest weather radar. If a weather radar is not available, the satellite imagery could serve as the basis for alerting the public. We emphasize the word "alert" to differentiate among "watch" and "warning". An "alert" could place the public on notice that tornadic conditions existed in current storms and could give a lead time up to 30 minutes to allow preparations. A notable example of how valuable an "alert" stage may be is the case of the Manford, OK, tornado which struck on Sunday, April 29, 1984. The tornado vortex signature was first noted by NSSL scientists at 0914 CST. Its location and direction of movement indicated it would pass over Manford before 10 CST. By informing the proper authorities, deaths and injuries where held to a minimum despite the fact that two churches experienced collapsed roofs. The local police where able to clear children from Sunday schools and shepard them to safety before the tornado struck at 0945 CST (Burgess, 1984).

The immediate objective of the research being reported on here is that of attempting to develop a statistical model which is representative of the distribution of tornadic intensities among a group of thunderstorm cells involved in a given tornado outbreak. We have limited the study to those outbreaks which produced 5 or more tornadoes. We shall discuss results for two outbreaks: Ohio, Pa, and NY storms of May 31, 1985, and the Iowa, Minn., WI outbreak of June 7, 1984. The 1985 oubreak was associated with a cold front passage and squall lines which produced some 29 separate tornadoes in the U.S. and 13 tornadoes in southern Canada. These tornadoes caused 74 deaths and 850 injuries in the U.S. alone plus millions of dollars in property damage. The June 7 outbreak produced 42 tornadoes in the upper midwest with 21 of them tracking through Iowa. There were two main clusters, one extended from northwest Iowa into south-central Minn. and the second through southwest Iowa into southwest Wisconsin. Together the tornadoes caused 13 deaths and 319 injuries along 584 miles of damage path.

## 2. DESCRIPTION OF TECHNIQUE

We first matched the tornadoes to their parent thunderstorm cells using satellite imagery, the McIDAS system, and Storm Data reports. The two parameters: anvil outflow strength (UMax) and storm relative anvil deviation angle (SDA) were estimated by fitting a 2-D numerical anvil flow model envelope to each anvil from the separate thunderstorm cells that were visible during the tornadic phase of the synoptic activity. In the May 31 case, we identified 22 separate cells and made measurements on each. 14 of the cells were non-tornadic while 8 produced tornadoes. 5 of the tornadic cells produced 25 tornadoes, all involving Fujita scale strengths ranging from F0 to F5. The 3 other tornadic cells produced F1 tornadoes only. In the Iowa case we identified 7 tornadic cells and 5 non-tornadic cells. One cell alone produced 23 tornadoes.

A given cell's tornadic productivity was calculated by assigning a numerical value to each tornado it produced according to Table 1.

Table 1

| Fujita scale rating | Tornadic Intensity | |
|---|---|---|
| | $\overline{Fw}$ | $\overline{Fw^2}$ |
| F0 | 1 | 1 |
| F1 | 2 | 4 |
| F2 | 3 | 9 |
| F3 | 4 | 16 |
| F4 | 5 | 25 |
| F5 | 6.25 | 42.25 |

The weighted mean squared of the total tornado production of a given cell was calculated according to the table. For example, a cell which produced (2)F1, (2)F2, (4)F3 and (6)F4 tornadoes was assigned a weighted mean squared value of 17.14. If a cell produced no tornadoes, its weighted mean squared value was zero.

The results for the May 31 case are given in Table 2.

Table 2

| Cell Number | $\overline{Fw^2}$ | UMax | SDA |
|---|---|---|---|
| A | 0 | 15 | 14 |
| D | 0 | 2 | 1 |
| E | 0 | 10 | 0 |
| F | 0 | 3 | 1 |
| G | 16.7 | 25 | 38 |
| K | 4 | 20 | 22 |
| L | 0 | 10 | 18 |
| O | 4 | 20 | 29 |
| Q | 0 | 5 | 5 |
| R | 0 | 6 | 8 |
| U | 0 | 10 | 1 |
| V | 0 | 15 | 20 |
| W | 0 | 19 | 16 |
| B+C | 17.1 | 38 | 30 |
| I | 8.7 | 26 | 20 |
| J2 | 10 | 31 | 20 |
| M | 4 | 20 | 25 |
| X | 0 | 10 | 22 |
| H | 17.42 | 25 | 47 |
| Z | 0 | 15 | 22 |
| AA | 0 | 22 | 14 |
| Y | 0 | 2 | 5 |

The results for the June 7 case are shown in Table 3.

Table 3

| Cell Number | $\overline{Fw^2}$ | UMax | SDA |
|---|---|---|---|
| A | 9 | 22 | 21 |
| B | 16 | 25 | 22 |
| C | 11.75 | 27 | 27 |
| D | 7.52 | 50 | 17 |
| E | 0 | 12 | 9 |
| E' | 0 | 12 | 8 |
| H | 0 | 12 | 10 |
| J | 7.33 | 24 | 13 |
| J' | 6.5 | 20 | 13 |
| L | 0 | 8 | 8 |
| I | 0 | 15 | 9 |
| G | 1 | 12 | 14 |

The data in Tables 2 and 3 were examined using a bivariate regression model where the tornadic intensity was the response variable and UMax and SDA were the predictor variables given by the equation:

$$Y = \beta_0+(\beta_1x_1+\beta_2x_2)+(\beta_{11}x_1^2+\beta_{22}x_2^2+\beta_{12}x_1x_2) +....$$

First, second, third and fourth degree polynomial variance analyses were carried out on the May 31 data and first, second, and third degree polynomial variance analyses were tried on the June 7 case. The results of these analyses are shown in Tables 4 and 5.

Table 4

Results of Bivariate Regression for May 31 Data

| Degree of Polynomial | Coefficient of determination $R^2$ | Differences |
|---|---|---|
| First | 0.6897 | |
| Second | 0.9411 | 0.2514 |
| Third | 0.9732 | 0.0321 |
| Fourth | 0.9966 | 0.0234 |

Table 5

Results of Bivariate Regression for June 7 Data

| Degree of Polynomial | Coefficient of determination $R^2$ | Differences |
|---|---|---|
| First | 0.8054 | |
| Second | 0.9877 | 0.1823 |
| Third | 0.9976 | 0.0100 |
| Fourth | (Model is not of full rank) | |

The tables indicate that a quadratic bivariate model is able to account for over 90% of the variation in the response variable by the two predictors, UMax and SDA. The results were not as good when the data were lumped; even for a fourth degree of regression the coefficient of determination was only 0.9054. We calculated the coefficient for the combined cases where we translated the coordinates of the Iowa data to fit those of the Ohio-Pa data. Here, the fourth degree regression improved to an $R^2$ value of 0.9535 whereas the quadratric was only 0.8937. These results indicated to us that the two data sets represented two different types of tornado outbreaks and one would get better results if they were treated separately. The synoptic situations in the two cases differed; May 31 was a triggered by a cold front and squall lines, while June 7 was the result of upper level disturbances moving through an extremely powerful jet maxima over the upper midwest which had a very unstable airmass. It is our hope to be able to group various outbreaks into separate categories, each being defined by some significant characteristics. In this regard, we note that the model represents a "rising ridge" whose separation point from non-tornadic cells differs in the two cases (Box and Draper, 1987). Both cases indicate that the tornadic intensity of the storms increase as one ascends the ridge. These points are illustrated by the graphs for each case shown in Figures 1 and 2. We see that the separation point between tornadic and non-tornadic cells for May 31 lies near UMax = 19, SDA = 16 whereas for June 7 the separation point lies near UMax = 16, SDA = 10.

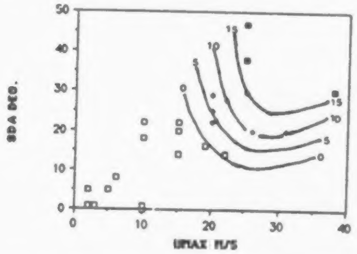

Fig. 1. May 31 case. Simulated deviation angle (SDA) vs maximum radial outflow velocity. Lines represent $\overline{Fw^2}$ values: □ = 0, .◆ = 4-10, ● > 15.

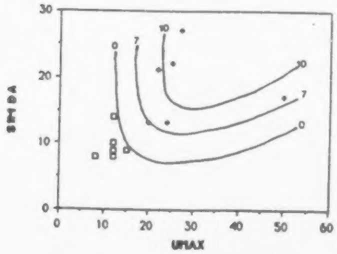

Fig. 2. June 7 case. Simulated deviation angle (SDA) vs maximum radial outflow velocity. Lines represent $\overline{Fw^2}$ values: □ = 0-1, ◆ = 5-9, ● > 10.

Another way of assessing how well the model equation fits the data is to plot the model values for the tornadic intensity of each data point shown in Figs. 1 and 2 versus their actual values. These results are shown in Figures 3 and 4. Y, Y hat, is the model value and Y, is the measured tornadic intensity of a given cell. Both figures represent optimum fits obtained using 3rd and 4th degree polynomial regressions, respectively. The graphs illustrate that the model tornadic intensity for a cell agrees very well with the measured value, even for those cells with zero values.

Finally, we wish to demonstrate that the rising ridge approximation appears valid for the two outbreaks we examined. Although two cases cannot be used to argue the generality of this approximation, nevertheless we were pleased to see that it seemed valid for the two cases as shown in Figure 5. Here we have made the coordinates non-dimensional by dividing the entire May 31 set by its separation point values for SDA and UMAX and a similar transformation was made for the June 7 set. Thus the separation points equal 1 for the axes values for both cases. In Figure 5, with a few exceptions, both cases seem to overlay well in terms of the tornadic intensities of their cells.

## 3. DISCUSSION OF RESULTS

Previous studies (Waisman and Klemp, 1982; Colquhoun and Shepherd, 1985, Rasmussen and Wilhelmson, 1983) among others suggested a connection between tornadic storm development, storm strength (e.g. mass flux, buoyancy, potential buoyant energy etc), and vertical wind shear (e.g. 0-4 km wind shear, relative helicity, etc). Our approach has been to use a 2-dimensional plume simulation to outline the visible anvil plume in the satellite imagery and to note the values of the two input variables we use to manipulate the growth rate and direction of the simulation. We control the speed of growth by specifying the maximum radial outflow velocity at a given distance from the point source of the anvil material and we control the angle of deviation of the centerline of the plume from the storm relative wind by introducing a tangential component to the radial flow. When we judge that we have a good fit between the envelope of the simulated plume and that of the actual plume over a few time steps, we record the values of the input parameters.

We believe our input parameters involve similar physical bases as the studies mentioned above. We believe the UMax is a good index of the storm mass flux and that SDA somehow measures the helicity of the updraft, although we have been unable to demonstrate this using the Schlesinger 3-D thunderstorm model.

## 4. FUTURE WORK

We intend to analyse a number of tornadic outbreaks using this technique. We hope to be able to sort them into a limited number of categories based on their "separation point" threshold between non-tornadic and tornadic cells. We hope also to be able to

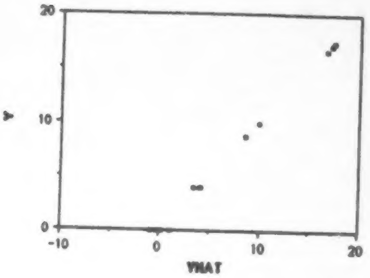

Fig. 3. Y vs $\hat{Y}$ for May 31 case. Plot is for 4th degree regression results.

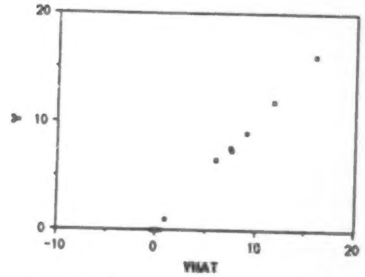

Fig. 4. Y vs $\hat{Y}$ for June 7 case. Plot is for 3rd degree regression results.

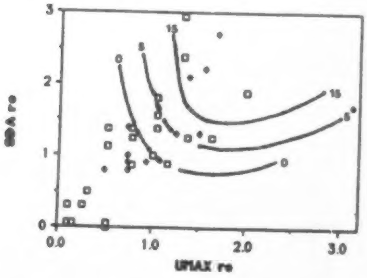

Fig. 5. Plot of non-dimensional data from May 31 and June 7 cases. Simulated SDA and UMAX values are divided by the separation point values for each set. Isolines represent tornadic intensity levels as shown in Table 2 and 3.

▫ = May 31, • = June 7

forecast the type of category for an announced watch area using standard meteorological data such as instability indices, vertical wind shear, calculated helicity values, etc. As cells develop, their UMax and SDA values could be measured using satellite imagery and McIDAS and a forecast could be made of their tornadic potential.

## 5. ACKNOWLEDGEMENTS

This research has been supported by NASA Contract NAS8-36547. We wish to thank Dr. Robert Schlesinger, Department of Meteorology, for the development of the 2-D anvil plume model, and David Santek, Space Science and Engineering Center, for its adaptation to McIDAS, both of University of Wisconsin-Madison, and Miss Gerri Furlow, Department of Statistics, North Carolina State University, for her able assistance with the statistical aspects of this work.

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Mr. Price. Thank you, Dr. Anderson, and without objection we will include the article that you submitted, co-authored with Dr. Schrab, in the permanent hearing record.

Dr. Brotak.

Dr. Brotak. Thank you.

First let me address a point that was brought up earlier. I guess the question is is Accuweather getting information from the National Weather Service that other people are not getting. I do not think that is the case. I think what happens is that the various forecast centers in the National Weather Service send out technical discussions. These only go out—they do not go out to the general public, they go only to various meteorological groups. I know like at UNCA we get some of this information. It would be quite possible, say from the Severe Storms Forecast Center to send out a technical discussion saying that perhaps later in the afternoon we will be sending up a severe thunderstorm or tornado watch. Certainly Accuweather could read that and then use that for their own information to, you know, talk to their clients and tell them perhaps you are going to have a watch issued. So I do not think anybody is getting any special information.

Mr. Price. Well that was not really the thrust of my question. I was rather interested in why the television stations subscribed to this private service, what it is that they got from the private service that the National Weather Service did not provide. That was what I was attempting to clarify. Can you explain that? Is it interpretation, is it an alternative source of data or are there capabilities there that the government agency itself does not have?

Dr. Brotak. To a certain extent, because they can be much more specialized. They can assign one person to do a forecast for one reason. I think a lot of it is just the fact that for certain TV or radio stations, they think it sounds better in advertising to say we have an Accuweather forecast rather than just saying we have a National Weather Service forecast. So I think some of it is just advertising.

Mr. Price. Okay. Go ahead with your statement please.

Dr. Brotak. I would like to just summarize the points I made in my written statement.

First in regard to the Raleigh tornado, from my examination of the event, I do not think it was a forecastable situation. I do not think there is any way in advance you could have forecast the occurrence of a major tornado such as we had. The first thing to remember of course is that tornadoes east of the Appalachians are very rare. And any rare event is going to be very difficult to forecast.

This particular weather system, which as was pointed out had moved across the country and had produced severe weather west of the Appalachians. That, however, is not unusual. It is very unusual for a weather system to move across the Appalachians and produce severe weather on the east side of it, and most times—in this particular situation which we are dealing with here, it was not that unusual. We have seen many situations like this which moved across North Carolina and have not produced severe weather. I think it was just an unusual combination of circumstances.

During the day on that Sunday, the system moved across North Carolina, did not produce any severe weather and really what happened, the thunderstorms developed explosively pretty much in the Raleigh area. One of the hardest things to do is to forecast an event which develops on top of you. That is almost impossible and unfortunately it happened to occur in a populated area.

Now the question is, once the thunderstorm develops, is there any way to determine could they produce tornadoes. From everything that I have heard of the conventional radar data that was available, there was no way of telling this. The storms apparently appeared on radar certainly as not being of the criteria for producing tornadoes.

Now the next thing is what have we learned from this, is there anything we could do in the future to prevent this from happening. Certainly the question of Doppler radar has come up. Doppler has a much better capability of determining if a thunderstorm can produce tornadoes. Would this have helped in Raleigh? Obviously there is no way of knowing in hindsight if a Doppler radar could look at the thunderstorm and determine if it is going to produce a tornado. One thing I think is important for the public to know is that Doppler radar is not going to be the answer to all tornado forecast problems. There will probably, even when all the Doppler radar units are in place, there will probably still be some unforecasted tornadoes. Whether or not it would have helped in this situation, I think the only thing you can say is it might have helped. And I think when you are talking about a loss of life, then that certainly justification. Just saying you might have been able to prevent the loss of a live, that would be enough justification to put the money into it.

Certainly we need more research on tornadoes in the eastern part of the country. Definitely from the situations I have looked at, and I have lived in the east all my life, the situations which produce tornadoes in the east are different than situations which produce tornadoes in the plains states and the midwest. Almost all of our research has been done in the plains states and midwest because that is where most of the tornadoes are.

Mr. **Price**. Are you talking now about government research or are you talking about university research?

Dr. **Brotak**. Not just government, also university research. Almost all of it has been done in the plains states and midwest because that is where most of the tornadoes are. Like Oklahoma University in Norman, they do a lot of research on tornadoes, they are right in the middle of tornado alley.

Mr. **Price**. But the nature of storm formations east of the Appalachians would justify a particular emphasis on that area as well?

Dr. **Brotak**. I think so, because I think the situations are different. I think the situations which develop into tornado producing storms are different because I have seen, now the two cases in North Carolina, I have seen some up in the northeast. Also apparently the thunderstorms which produce tornadoes are different, because the radar criteria the Weather Service uses to determine if a storm can produce a tornado was basically developed in the plains states. As we have seen, there are storms which produce tornadoes in the eastern part of the country which do not fit this criteria, appear to be non-severe. So I think there is definitely a need for research here in the east.

The final point here has been discussed a little bit about the effect of budget cuts. I think the best way to prevent this kind of situation from happening is to have fully staffed National Weather Service offices equipped with the latest technology.

We have heard a little bit of talk about what is happening in the Weather Service now. I do not think so far what I have heard described nearly tells how bad it is. I have a number of contacts, I have some of my former graduates work for the Weather Service, I have a number of friends there. From what I hear, I would say that many, if not most, National Weather Service offices are now under-staffed. In some cases severely so. A lot of cases, the technology which could be certainly used is not available. I think a good example is to look at what is happening with the GOES satellites. We need two GOES satellites to cover the United States. Right now we have one. This one satellite which is providing continuous surveillance of the United States, this could fail at any time. If it fails we have no backup satellites. We have no plans to launch another satellite probably for over a year. We will be without continuous satellite coverage. We will be down to just the polar orbiting satellites which only provide pictures like a couple of times a day. In other words, we will go back in time in terms of our technology in meteorology, back 20 years, just for budget constraints.

I think there is a serious question here of what are the priorities and I think someplace there are some displaced priorities, and I think the Weather Service definitely—the main duty of the Weather Service is to protect human life. I do not know how many other—now the Weather Service has done this, the Weather Service can prove that they have saved people's lives. I do not know how many other government agencies can prove that. I think certainly they can justify their funding.

Mr. PRICE. You are not talking about misplaced priorities within the Weather Service, you are talking about—

Dr. BROTAK. No, misplaced priorities I would say in terms of government spending.

Mr. PRICE. Yes.

Dr. BROTAK. Okay, that is basically what I would have to say right now.

[The prepared statement of Dr. Brotak follows:]

# Testimony Given To
# Subcommittee on Natural Resources, Agricultural Research, and Environment

Committee on Science, Space, and Technology
US House of Representatives

by

Edward A. Brotak

Dr. Edward A. Brotak
Associate Professor
Atmospheric Sciences Program
UNC Asheville

Presented
March 3, 1989

## Tornado Forecasting and Severe Storm Warning Systems

Tornadoes are the most destructive storms in nature and each year account for dozens of fatalities and millions of dollars of property damage in the United States. Because of this, meteorologists have spent much time and effort in trying to learn more about these storms with the goal of improving forecastability. Due to the relative rareness and small size of these storms, there is as yet no true way to forecast their occurrence. The National Severe Storm Forecast Center in Kansas City issues tornado watches usually several hours before any severe weather is occurring. A tornado watch covers hundereds of square miles and means that conditions within the watch area are favorable for the development of severe thunderstorms which could produce tornadoes. For the public, a tornado watch means be alert for changing weather conditions and continue to monitor radio or television for further statements. Tornado warnings are issued by local National Weather Service (NWS) Offices and only cover a county or two. A tornado warning is issued if a tornado has been reported on the ground or if certain weather radar criteria have been met. A tornado warning should be interpreted by the public as a "take cover".

Much of the basic research which has led to the criteria for tornado watches and the radar criteria for tornado warnings was accomplished in the Plains States and Midwest. These areas receive more tornadoes than any other region on earth. Based on my observations of tornado events east of the Appalachians, I would say that some of these criteria do not work. The overall weather situations which produce tornadoes in the East do seem to be different from those in the Plains States. Simply put, it seems that the air over the central part of the country is more unstable and needs less of a push upwards to produce severe thunderstorms. The air masses east of the Appalachians are not quite as unstable and require more lifting. The conventional weather radar criteria also seem to differ. The classic "supercell" thunderstorms of the Plains States paint vivid radar depictions. Often tornadic thunderstorms in the East are not nearly as large or impressive. Also, tornadoes are rare events east of the Appalachian Mountains. Although the lack of these destructive storms is certainly welcomed by the residents of the East Coast, it does cause problems in the forecasting of these events when they do occur. With the lack of occurrence of tornadoes in the East, good prototype models are lacking.

North Carolina has experienced two major tornado events in recent years. On 28 March 1984, North Carolina was hit by twelve tornadoes of which three were ranked as F4 on the Fujita Intensity Scale. The Fujita Scale ranks the weakest tornadoes as F0 and the strongest as F5. An F4 storm has winds over 200 mph and is capable of totally destroying even well built structures.

The 1984 tornadoes resulted in 57 fatalities. On 28 November 1988, North Carolina was hit by five tornadoes. The Raleigh Tornado was ranked as an F4 and resulted in four fatalities and damage over $100 million. There has been some controversy over this storm since the NWS isssued no watches or warnings prior to touchdown. One of the most difficult things to forecast is an event which develops right on top of you. This is, I believe, what happened in Raleigh.

North Carolina has a complex geographic setting with the Appalachian Mountains in the west and the Atlantic Ocean to the east. Often in the winter, cold air wedges down from the north along the east side of the Appalachians. Warm, moist air pushes in from the east off the ocean. At the same time, cold fronts moving in from the west are bringing in yet another air mass. It was this type of complex pattern that occurred on November 27 and 28. The warm, moist, tropical air off the Atlantic covered the state from Raleigh eastward. Colder, more stable air was in place to the west with an approaching cold front coming in from Tennessee. The precipitation which occurred ahead of this front was moderate and no severe weather occurred during the day on the 27th. However, as this sytem continued to move east and finally ran into the warm, moist unstable air over the Raleigh area, explosive thunderstorm development took place. It was in these thunderstorms that the tornadoes developed. Forecasting this situation in advance was probably impossible.

Once the thunderstorms developed, was there any way of telling if they were capable of producing severe weather? This is usually done by interpreting radar images. Currently, the Raleigh area is served by conventional radar. These radar sets determine precipitation intensity. There are guidelines which have been developed to infer severe weather potential from conventional radar depictions of thunderstorms, but once again, most of these were developed for areas west of the Appalachians. From what I have heard, the radar depictions of the storms in question did not meet the criteria for tornado-producing storms.

To combat this problem, the NWS, the FAA, and the DOD have pooled their resources and are replacing the conventional radar sets with new Doppler radar units. Doppler radar has the capability of determining air movements within clouds. It can peer into a thunderstorm and determine if rotation is present. If it is, then this spinning can become concentrated and later evolve into a tornado. Doppler radar has the capability of providing up to 20 minutes of lead time for a tornado warning before the tornado descends from the cloud. Of course, we will never know if a Doppler radar would have given an early warning for the Raleigh Tornado. Certainly, it would be a valuable tool for the meteorologists there.

The best way to prevent losses due to severe weather is to have fully-staffed NWS offices equipped with the latest technology to protect the population. Unfortunately, in recent years, just the opposite has occurred. Mandated budget cuts have severely hampered the NWS's ability to perform its duties. Many NWS offices around the country are seriously understaffed. The procurement of new equipment has been delayed or abandoned. One good example of this is the situation with our weather satellites. These satellites provide some of the first indications of developing storms. To adequately cover the United States, we need two geostationary weather satellites, a GOES East for the eastern half of the country and the Atlantic and a GOES West to cover the West Coast and the Pacific. Recently, GOES West failed, leaving just the single satellite to provide continuous surveillence. There is no back-up, and no new satellite launchings are planned for over a year. It is quite possible that the remaining GOES East satellite will also fail before new satellites are ready. This will leave us with only polar orbiting satellites which only provide imagery several times a day rather than continuously. This will be of no benefit for severe weather forecasting. In other words, we will go backwards in terms of technology nearly twenty years.

The main duty of the NWS is the protection of life. There is no doubt in my mind that if budget cuts continue and services have to be further reduced, that loss of life will result. The situation which occurred in Raleigh last November will become more common. The legal and societal consequences of these events will likely be much more catastrophic than is obviously imagined in Washington.

Mr. **Price**. Well, both of you heard the earlier budget discussion. Dr. Anderson, in bringing up the question of the length of time that this Doppler system has been under development, I mean to refer back to that discussion and I would like to ask you both what your reflections on that discussion would be. You both know the realities of research and development in this area, you both know what is reasonable to expect in terms of a time line for developing these systems and getting them deployed. Has the pace of development of the new technology been inordinately slow? To what extent have we had an underfunded program that really could have been on line long ago, but is not because of budget constraints? Can you contribute to that discussion which we got underway a few moments ago with the Weather Service officials?

Dr. **Anderson**. Well I agree with Professor Brotak in the notion that we should not look at the NEXRAD radar as being the panacea for tornado forecasting. We are going to find when we put these NEXRAD radars on line that we are going to get many, many false alarms because what we will be looking at will be signatures in the wind field due to precipitation that will indicate the presence of mesocyclones. So there is a tremendous amount of research that needs to be done in order to distinguish which mesocyclones are likely to become tornadic and which ones are not. We have had experience already with Doppler type radar being placed in the field both at the Stapleton Airport in Denver, at Norman in Oklahoma, at Huntsville in Alabama, where on a day when you have strong convection, you see mesocyclones everywhere. We have to have an additional criteria for determining which of these are going to become tornadic and which are not. This is why I am suggesting very strongly that we couple the Doppler message with the message that we are developing using satellite imagery to make that determination.

So that in on sense it may be well that the Doppler did not come on line too quickly because they were not prepared to interpret and handle the information that the Dopplers are going to generate. Our understanding of the physics and meteorology is not at the place, at the point in time, that we can fully utilize the Doppler. So I think there is a big misunderstanding out there in the general public that the Doppler radar is going to solve our problems. The Doppler radar is going to generate problems, generate many problems for the National Weather Service before that finally settles into some sort of operational procedure.

Mr. **Price**. That does still leave the question of the pace at which this kind of experimentation and development might be carried out. And my question to you, quite simply, is whether the pace of that experimentation and development is optimal? To a layman, the time that this has taken does seem to be rather stretched out.

Dr. **Anderson**. The little bit I know about it is that the government had to set up a joint committee because you were involving a number of different government agencies that were developing this one system, which would fulfill their particular needs. That is going to be time-consuming.

Secondly, there was a tremendous amount of interest in competing for this half billion or billion dollar funding that accompanied the building of these Doppler radars. So there was an intense competition period of two or three or four years before they finally awarded the contract to the one company that is going to do the production.

So you might think it is an inordinate amount of time, ten years, but on the other hand, from all the complexities that were associated with this development, it may not be.

Mr. **Price**. You do agree, though, with the report of the in-house team at the National Weather Service that if a Doppler system had been in place at Raleigh-Durham Airport on November 28, that probably some warning could have been given?

Dr. **Anderson**. I think there are a lot of inaccuracies in that report from the National Weather Service. For example, they say that there was no way that there would have been any idea that we would have had severe weather. Our own review of the Volens, Virginia radar tape shows that a squall line was lying just to the west of the Raleigh area for more than three or four hours and on that squall line we had a tornado develop one half hour earlier at a place called Alberta in Virginia, which was reported by the sheriff's deputies, which was reported over the scanners so the newspaper people got it. That information somehow never got into the pipeline either to the met tech at Volens, nor to the people at Raleigh.

Mr. **Price**. How would you normally have expected that information to be picked up?

Dr. **Anderson**. I do not know how they carry out their internal operations, but I would think that they should have some sort of infrastructure such that when a tornado is reported it gets into the hands of the proper authorities. The proper authorities were the sheriff's deputies and the sheriff's department in Brunswick County in Virginia. Now I asked where did that go or where would it have gone. Well they said it would have probably been reported to Roanoke. From there I do not know. But it seems very strange to me that here is a system that was known to produce a tornado, we can clearly see the cells moving in that system toward Raleigh, that nobody is willing to say that these could produce tornadoes later on.

Mr. **Price**. Now you are saying that picture would have been picked up at Volens; in fact, it was picked up at Volens?

Dr. **Anderson**. Oh, yes, it was, that picture was at Volens.

Mr. **Price**. Would it have been picked up at Raleigh-Durham if that system had been operative? Would it have been likely to be?

Dr. **Anderson**. I am not aware of what their radar capability is like. If we had heavy rainfall the Raleigh radar beam might have been severely attenuated even beyond the 25 mile radius in which you have a confusing picture.

I had a similar experiment—experience in Madison. We had an F5 tornado strike a little town called Barneville, 30 miles southwest of Madison. The tornado destroyed 90 percent of the town and killed nine persons. The tornado was seen by the Marseilles, Illinois radar. The radar at Madison was operative, it was not down, but they had no idea at Madison that a tornado was in being and it was the same kind of equipment that we have here at Raleigh.

The second point, that tornado was moving at the rate of 60 miles an hour. The characteristic signature that Weather Service people talk about and others talk about that should have been seen would not have been seen at that rate of speed because the entire reflectivity field would have been considerably altered.

So Mr. Chairman, what I am saying is that there is more brain power needed on this problem, more so than—perhaps as much as we are putting into hardware, we need to put more brain power to work.

Mr. PRICE. There is still a major research job to do.

Dr. ANDERSON. I am saying that we at North Carolina State University are accomplishing this research. I do not know if anybody will listen to us, but we are getting it accomplished.

Mr. PRICE. That is good to know and that is part of the purpose of the hearing we are having today.

Dr. Brotak, could you add your perspective on the pace of the research and development effort, particularly with respect to Doppler and the new computer system?

Dr. BROTAK. Well I think whenever you talk about the government purchasing equipment, it always takes a long time. If you go back to the AFAL system which the National Weather Service—it was their first attempt to get into computer communications, by the time they got the system in it was outdated. One of the problems is that technology is moving along so quickly, if you take years in terms of putting your new equipment in, by the time you get it, it will be outdated. I think it is definitely moving too slowly. Somehow we have got to find a way to speed up the process so we can utilize latest technology before it becomes obsolete.

Mr. PRICE. Is there any answer to that beyond the obvious funding implications, when you talk about speeding up the process?

Dr. BROTAK. Well I have had experience in our university system. You send in a purchase order and maybe a couple months later, they will send it out and maybe within a year you will get the equipment. I just think there is a lot of red tape and a lot of streamlining that could be done just in terms of getting the things done.

Mr. PRICE. Mr. Valentine.

Mr. VALENTINE. Dr. Anderson, you heard on the television, seen on the television and radio references to a staff meteorologist thus and so. You and Dr. Brotak are here to testify as professors of meteorology. Does the State College or North Carolina State University confer a degree in meteorology and does—I will ask the question of Asheville, and if so, do the gentlemen who pull out the charts and tell us about the weather on the television stations, are those people people who are graduates of the institutions such as yours?

Dr. ANDERSON. Some are and some are not. What I mean to say is that some stations employee professional meteorologists, those are persons who have earned a degree in meteorology, either at bachelors or masters level. There are other persons who are simply news announcers who give the weather using prepared text that is done by private companies or some other source. So that the authenticity of a forecast that you hear over the air may not come from that individual who is giving it's personal knowledge, it is coming from what he has as notes in his hand at the time.

Mr. **Valentine**. Are you saying that when a television station refers to someone as staff meteorologist, it might not necessarily mean that that individual has any formal training in that field?

Dr. **Anderson**. That is correct.

Mr. **Valentine**. I find that very interesting. You could call anybody a doctor I suppose or you could call anybody a lawyer, but do you see any problem with that? Should maybe we have an opportunity to know whether the person who tells us about the weather is a showman or a meteorologist or does that not make any difference?

Dr. **Anderson**. Well the American Meteorological Society, which is the professional organization for meteorologists, has a certification procedure in which they will award the AMS seal of approval to a staff meteorologist who is able to complete a satisfactory examination given by the American Meteorological Committee on AMS field. That, as far as I know, is the only certifying body or certification that is in existence.

Mr. **Valentine**. Do you keep up with your former students enough to know whether or not the students who take your courses go to work for the Weather Service or radio and television stations?

Dr. **Anderson**. Most of my students go into a teaching profession, they become professors other places, or they return to the military and render a service to the country or they go into private industry as experts in atmospheric problems. Very few of my students go into weather forecasting for radio and TV.

Mr. **Valentine**. Excuse me, I did not hear whether you said that the college or university does confer a degree in meteorology.

Dr. **Anderson**. We confer a bachelors, a masters and a Ph.D. in meteorology.

Mr. **Valentine**. Okay.

Dr. **Brotak**. Our school is an undergraduate school so we just offer a bachelor of science degree in meteorology. We have a number of students in the Weather Service. We also have two students right now working in television. The last figures I heard was about 50/50 in terms of TV people either having a degree or at least the AMS seal. By the way, getting an AMS seal means you have to have I think about 20 credits in meteorology, it does not mean you have to have a degree. It just means you have some experience and you have to have some courses.

In terms of whether or not the people are qualified depends on the station that is doing the hiring and depends—here again, a lot of times it does not really depend on if they want to have good quality information, they depend on economics, ratings. If they feel they can get good ratings by having a professional meteorologist, they will have a professional meteorologist. If they think they can get better ratings by having clowns doing the weather, they will hire clowns. If you look at what is on some of the national television, you will see some clowns.

[Laughter.]

Dr. **Brotak**. Also some of the bigger stations, if you look at New York City, I used to live up around there, you will see some interesting people doing the weather, but that is just to get ratings, not because they know what they are doing.

Mr. VALENTINE. Thank you. I find that a very interesting and worthwhile comment. I want to tell you I agree with you. I waited until they turned the cameras off before I said that though.

One or two other questions. I wish I had had an opportunity to ask this question at the beginning of the meeting, but we did not. Do I correctly understand that a squall line is just a line of showers, a rain line?

Dr. ANDERSON. Thunderstorms and rain showers, yes.

Mr. VALENTINE. I would like to ask you gentlemen if you would do this for my edification if nobody else's, beginning with Dr. Anderson, tell us in a few words what is the difference between a tornado, a cyclone, a typhoon and a hurricane.

Dr. ANDERSON. The last three are the same thing, a hurricane is a tropical storm that occurs in the Atlantic or Caribbean region. A cyclone is called that in the Pacific region particularly in Australia, India areas. A typhoon is simply a hurricane that is another tropical storm that travels through the Indies and up through Japan and China. So that they are three masses, rotating tropical storms that originate near the equator.

Mr. VALENTINE. And they are called different names—

Dr. ANDERSON. A tornado is a different entity altogether because now you are dealing with a meteorological phenomena which is on the scale of a single thunderstorm that is rotating, so you are talking about something that has a scale of no more than a mile or two at most in diameter, where as in a hurricane you are talking about a phenomenon that is rotating that has a scale of several hundred kilometers. And the intensity of the winds that are involved in the two phenomena probably is two or three to one in the case of a tornado as opposed to a hurricane.

Dr. BROTAK. Can I add a couple of —

Mr. VALENTINE. Yes, sir, please. The last three just is a question of where they occur?

Dr. ANDERSON. That is right.

Mr. VALENTINE. I always thought—so Dorothy Lamour, when she played in a hurricane in the Pacific, somebody made a bad mistake, did they not? Never mind.

[Laughter.]

Mr. VALENTINE. I understood—I remember the movie, I do not expect anybody else here to, hurricane, I do not expect anybody here to remember Dorothy Lamour, but I thought that she was doing her wiggling in the Pacific, maybe not, maybe it was in the Caribbean.

Dr. BROTAK. By the way, there are hurricanes in the Pacific, in the eastern part of the Pacific we do have hurricanes, in the western part we have typhoons.

Mr. VALENTINE. Oh, I see.

Dr. BROTAK. We just like to confuse people.

Mr. VALENTINE. Well you have succeeded.

Dr. BROTAK. That is the whole purpose of meteorology, to confuse people, then you do not know we are wrong.

The purely scientific definition of a cyclone is any low pressure area, so technically a hurricane or tornado or normal low pressure area you see on the daily weather map is a cyclone. I think the confusion has arisen because out in the middle part of the country people a lot of times refer to tornadoes as cyclones. If you are a meteorologist, okay, a tornado is a low pressure area, so it is a cyclone, but our definition is much broader than what a cyclone is. It is also used, as Dr. Anderson said, a cyclone is a tropical cyclone over the Indian Ocean. But I think there is some confusion. But again, like he was saying in terms of size, a hurricane or typhoon, we are talking about hundreds of miles, the biggest tornadoes are maybe a couple of miles across.

Mr. VALENTINE. What is the difference between a tornado and a water spout?

Dr. BROTAK. Well the simple definition we use in meteorology, a water spout is a tornado over water, which is not true in most cases. A small vortex very often will form in a developing cumulus cloud, not really a thunderstorm. Normally most water spouts are fairly weak and do not do any damage. There are exceptions to that, there are some true tornadoes over water but normally water spouts are a different type of phenomenon.

Mr. VALENTINE. Thank you, Mr. Chairman. Thank you gentlemen.

Mr. PRICE. Let me just add one follow up question, Dr. Anderson, and this will be very quick. You did talk about your experimental efforts; you referred to, I think, the McIDAS work station.

Dr. ANDERSON. Yes, sir.

Mr. PRICE. That raised a question in my mind to what extent the equipment, the technological capabilities that you have at North Carolina State are possessed by the Weather Service. Do you have equipment, facilities that go beyond what the Weather Service possesses?

Dr. ANDERSON. Yes, sir.

Mr. PRICE. Could you elaborate?

Dr. ANDERSON. We have a McIDAS work station which is linked to the University of Wisconsin Space, Science and Engineering Center, which has the capability of acquiring data from the geosynchronous satellite as well as acquiring data from the normal weather services, both services and upper air. We can bring these data down to our work station via AT&T telephone lines and display the information on a video screen, as well as carry out a number of operations using that. The Weather Service does not have that capability.

Mr. PRICE. Would they, with the new AWIPS system that is being discussed?

Dr. ANDERSON. It may have some aspects of it but it will not be as sophisticated as the McIDAS system. There was an early version of the McIDAS that was purchased by Kansas City which is there now that they are able to do some things with, as Fred Ostby can tell you. But the research that we do where we have to measure the outflow plumes from these rotating thunderstorms and make a declaration as to whether or not they possess tornadoes is a much more advanced system than what they possess at Kansas City.

Mr. PRICE. You both have talked about the need to upgrade our research efforts, and you have made very clear that there is no panacea in this area, that even when the Doppler system goes on line there will continue to be a research and development agenda. How extensive is the research effort nationwide in this area? That is a very general question of course and goes beyond the scope of these hearings, but I wonder if it is something you could just give us some general idea of the scope of the research effort that this country has underway, perhaps the way it compares with what other countries have underway and the extent to which the Weather Service and the government is setting and funding that research agenda.

Dr. ANDERSON. The Meteorological Society has a subgroup called the Severe Local Storm Committee. This Committee holds meetings every two years at some locality in the country where they have a conference for individuals interested in severe local storms and tornado phenomena. Those meetings are attended by up to 500 persons who give papers, presentations, present films and the whole variety of outcomes of their individual research efforts. So I would say that the United States is probably the leading country in the world in doing research on this type of phenomena and I find it taking place in many locales.

Within the National Weather Service itself, within different universities, with some private companies, all have some type of interest in this because it is a very pervasive phenomenon, as we know. We get more than a thousand tornadoes a year, which is very unique in terms of worldwide. There is a large body of interested people out there and there is quite a bit of different types of research ongoing.

Mr. PRICE. Do you have any ballpark estimate of the mix of public funds that underwrite this research and to some extent determine the agenda?

Dr. ANDERSON. Well I would think that the bulk of the public funding for this type of research comes from the National Science Foundation and from NASA. The Weather Bureau has been very miniscule in supporting this type of research outside of their own offices, perhaps because of their own lack of funding.

I would urge that the Weather Service look to these other sources. For example, the techniques that the Weather Service is still using in Kansas City to make their forecasts, to put out their watches, is based on research that was done in 1951, to so-called composite analysis. We urge that they come into the modern era. It takes money to do that.

Mr. PRICE. Yes. Do you have anything to add?

Dr. BROTAK. I think there is a lot of research being done in universities in terms of severe storms. I think one of the things in terms of getting new students, students are interested in this kind of thing. I think there is never a lack of students to get involved in graduate research. There does seem to be money available from the National Science Foundation and also the NRC provided some money.

I think one of the problems is we also should be doing research at the National Weather Service. One of the ideas of automating National Weather Service stations was to give the employees time to do some research, to sit down, like in Raleigh, for the people on duty and other people working there, to sit down and analyze the situation, do a post-analysis of it and be able to say okay, is there anything we could have done to make the forecast better. I think with the problems with the budget cuts and the lack of personnel, they are not really going to get a chance to do this.

Mr. Price. Thank you. We have benefited from your testimony and indeed from all of our witnesses this morning and we are grateful to all of you.

I have been especially pleased to have a number of elected officials from this area here this morning. We heard earlier from Mayor Upchurch of Raleigh and Mayor Moody of Rolesville. We also had Mayor Lucy Allen of Louisburg, former Mayor Alfred Johnson of Fuquay/Varina, and the Mayor of Wake Forest, Jimmy Ray, have all been here this morning and we appreciate their presence and their interest.

We are grateful again to the Subcommittee, Curt Stanford and other staff members. Mary Colletti of my staff has had a major role in these hearings and also Rachel Perry, Bobby Stott and others on my staff.

So again, let me just say thank you to everyone who has helped us have what I believe has been a very informative, very useful set of hearings. We will take this information and make good use of it as we look at the prospects for the National Weather Service in the years ahead and particularly as we undertake to draw up an authorization bill.

Congressman Valentine, do you have anything to add?

Mr. Valentine. I think you have covered it very well. I would like to say I appreciate everybody who testified and for those who helped make this possible.

Mr. Price. Thank you and subject to the call of the chair, the Subcommittee is adjourned.

[Whereupon, at 1:00 p.m., the Subcommittee was adjourned.]

# APPENDIX

## NATURAL DISASTER SURVEY REPORT
## TO THE ASSISTANT ADMINISTRATOR FOR WEATHER SERVICES

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

## THE NORTH CAROLINA TORNADOES
## OF NOVEMBER 28, 1988

FEBRUARY, 1989
BOHEMIA, NEW YORK

# DISASTER SURVEY TEAM MEMBERS

**Team Members**

Stanley E. Wasserman, Chief, Meteorological Services Division, National Weather Service, Eastern Region

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The survey was conducted in North Carolina between November 29 and December 1, 1988. Team members visited the damaged areas and spoke to victims of the disaster in Wake, Franklin, and Nash Counties. The team interviewed State, County and local officials; media representatives; and National Weather Service (NWS) employees. Information was obtained from the National Severe Storm Forecast Center in Kansas City, Mo. University of Chicago staff members provided the storm tracks based on aerial reconnaissance.

The survey team wishes to thank numerous individuals who cooperated in giving their time and assistance. These included personnel of the NWS, State officials, City and County officials, members of the news media and disaster service personnel. Their help made this report possible and will contribute to improvement in the NWS warning system. We are especially thankful for the assistance provided by Dr. Joseph M. Pelissier, Deputy Meteorologist in Charge and Dennis M. Decker, Warning Preparedness Meteorologist, both of the Weather Service Forecast Office, Raleigh-Durham, North Carolina.

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## EXECUTIVE SUMMARY

The November 28, 1988 tornado outbreak in North Carolina confirmed the requirement for a strong warning preparedness program; and showed frailties and obsolescence in the NWS observing, communication, and forecasting systems.

Beginning at 1:00 AM E.S.T., Monday, November 28, 1988, during the dark of night, tornadoes in North Carolina caused $77 million in damage, injured 157 people, and left 982 homeless. Miraculously, only four people died.

Tornadoes, particularly the ones of this scale and destructive strength, rarely happen during the cool season in North Carolina. The track of one tornado was 84 miles and was estimated at its onset as F4 severity on the Fujita Scale (winds estimated 210 mph). Considering the amount of damage caused by this outbreak, it was astonishing the death rate was so low. Even where there was little or no warning lead time provided, the response of people was correct: heading toward the center of the home, and evacuating trailer homes. Because of complete warning preparedness planning and public education, the disaster in North Carolina resulted in low casualties.

National Weather Service (NWS) offices in North Carolina in some cases did not provide advance warnings to the public. No watch was issued prior to the initial tornado. Many factors contributed to this. With the local radar equipment out of service at the Raleigh forecast office and no indication of severe weather from neighboring radars or national guidance, the forecast office was staffed for routine weather (two meteorologists and one meteorological technician). This staff was not sufficient to handle quickly the rapid, significant increases in workload once damage reports and observations of severe weather began to be received.

A thunderstorm intensified very suddenly into a tornado in the vicinity of the forecast office and then moved rapidly to the northeast. During the storm there was never a "confirmation" of a tornado from any radar echoes, or satellite imagery,nor were spotters available readily at that hour of the morning. The performance of National Weather Service personnel was reasonable using the tools and procedures available to them.

The inadequacies of the NWS radars to display tornado signatures were a major factor in the response of all offices. At the Cape Hatteras Weather Service Office, with the threat of tornadoes in the area, electronics technicians were called in to fix the radar. After the radar was repaired, a commercial power outage at the height of the storm prevented the timely issuance of a tornado warning. The Wilmington, NC Weather Service Office issued no warnings. This office was experiencing a staff shortage and decided to "tough it out" by not bringing in additional staff. During the entire night there were no indications on their network radar of severe weather and no reports of severe weather events from local officials even though a tornado occurred.

Limitations in communication equipment design, and deficiencies in operational procedures used by the NWS and the media in the dissemination of NWS warnings led to these warnings being delayed or not transmitted to the public. In addition, our scientific understanding of the atmospheric mechanisms producing severe storms and the database in support of such proved inadequate.

Many of the equipment and dissemination limitations are addressed in current NWS plans for system acquisitions and modernization. Better storm detection will improve our understanding of storm development.

Updated ground systems and data integration systems will give forecasters composite and coherent views of ongoing events. Graphic data sources coupled with forecasting expertise at the local level are essential to the correct and immediate interpretation of meteorological phenomena and the judgments which flow therefrom. Small-scale, rapidly developing severe weather phenomena are not quickly discernible by national guidance centers.

Overriding all is a compelling, almost desperate, need to upgrade and replace the nation's aged system of weather radars. These actions must be expedited to prevent another devastating surprise such as we witnessed on November 28, 1988.

Specific findings and recommendations appear in Chapter 8.

# CHAPTER 1 - DESCRIPTION OF THE TORNADO OUTBREAK

At 0100, Monday, November 28, 1988, a tornado with F4 intensity touched down in Raleigh, NC. (all times E.S.T.). The funnel stayed on the ground continuously until 0245, moving at about 50 m.p.h. toward the northeast for a distance of 84 miles. The tornado width ranged from a few hundred feet to about a half mile. It passed through parts of Wake, Franklin, Nash, Halifax, and Northampton Counties before lifting. At about 0250, a tornado, apparently associated with the same cell, again briefly touched down near Galatia in Northampton County for a distance of two miles before lifting. The storm spawning the tornado continued its northeast movement, crossed into Virginia and then, at about 0320, a tornado touched down north of Franklin, VA and stayed on the ground for about 15 miles until about 0335. This tornado hit Walters, VA. Earlier another tornado struck Virginia at about 0130 and stayed on the ground for about seven miles near Alberta in Brunswick County. Figure 1 shows the path of the tornadoes. Tornado track and length information are based on information provided by a University of Chicago tornado track survey team.

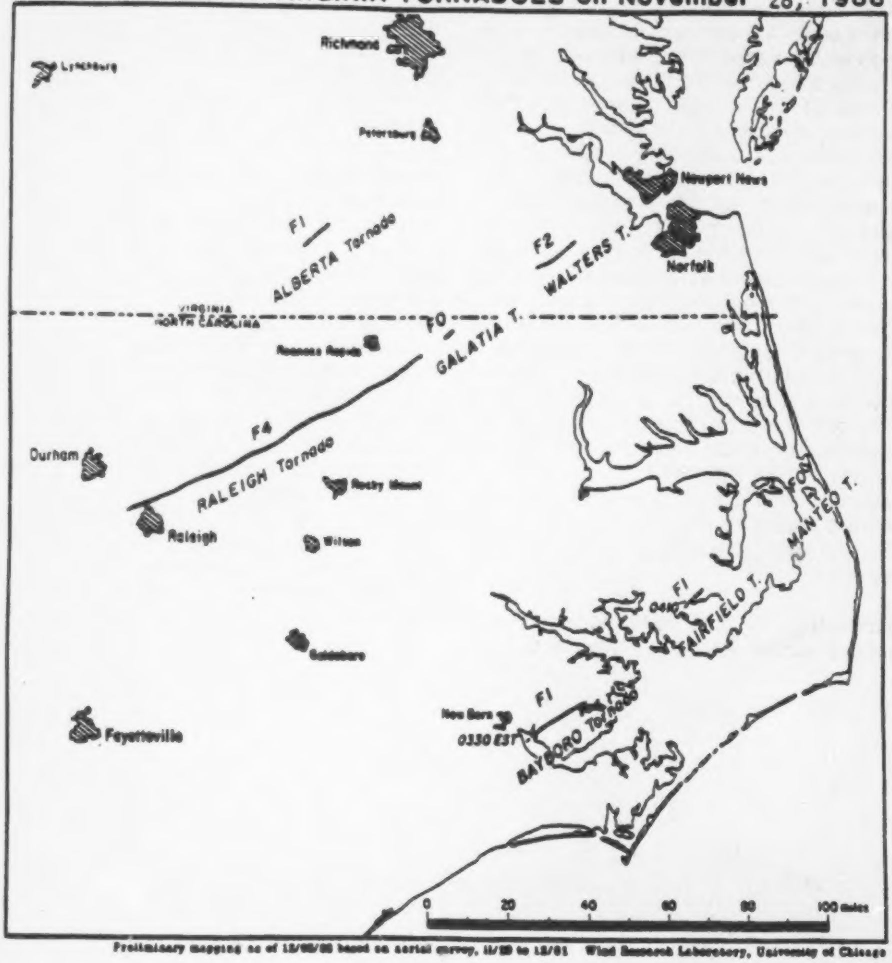
Between 0330 and 0549 additional tornadoes struck Pamlico, Hyde, and Dare Counties in coastal North Carolina with path lengths of about 30, 4, and 1 miles respectively. The Pamlico County tornado was on the ground for about 30 percent of its path, lifting up and setting down at various locations.

The first reports of damage were received at the Weather Service Forecast Office (WSFO) in Raleigh on the National Warning System (NAWAS). The tornado was on the ground for fifteen minutes before these first reports were received. During this time, the tornado (moving at 50 m.p.h.) caused tremendous damage and put people at risk along a twelve mile path. Telephone reports of the storm were difficult to make from the damage area since lines were down and people were busy taking action to survive. People outside the damage area could not see a tornado because it was night, raining heavily, and most people were indoors. There was never, during the storm, a confirmation of a tornado from any radar echoes or spotters.

Table 1 is an assessment by the State of North Carolina of the damage, injuries and deaths caused by tornadoes in North Carolina.

FIGURE 1

NORTH CAROLINA-VIRGINIA TORNADOES on November 28, 1988


Richmond
Lynchburg
Petersburg
Newport News
Norfolk
F1
ALBERTA Tornado
F2
WALTERS T.
VIRGINIA
NORTH CAROLINA
F0
GALATIA T.
Roanoke Rapids
F4
RALEIGH Tornado
Durham
Raleigh
Rocky Mount
Wilson
Goldsboro
Fayetteville
F0
MANTEO T.
F1
0410
FAIRFIELD T.
F1
New Bern
0330 EST
BAYBORO Tornado
0
20
40
60
80
100 miles

Preliminary mapping as of 12/02/88 based on aerial survey, 11/29 to 12/01 Wind Research Laboratory, University of Chicago

| COUNTY | HOMES DAMAGED | HOMES DESTROYED | BUSINESSES DESTROYED | INJURED | DEATHS | HOMELESS |
|---|---|---|---|---|---|---|
| Hyde | 9<br>(includes 1 mobile) | 1 | 1 | 0 | 0 | 3 |
| Dare | 11<br>(includes 9 mobiles) | 6 | 0 | 0 | 0 | 14 |
| Pamlico | 0 | 5<br>(includes 2 mobiles) | 0 | 3 | 0 | 12 |
| Northampton | 10 | 8<br>(includes 2 mobiles) | 3 businesses,<br>1 country club | 0 | 0 | 13 |
| Wake | 1586 | 128 | 35 | 105 | 2 | 800 (city)<br>30 (co.) |
| Nash | 10<br>(includes 3 mobiles) | 11<br>(includes 3 mobiles) | 0 | 22 | 2 | 70 |
| Franklin | 22<br>(includes 5 mobiles) | 27 (18 mobiles)<br>3 churches destroyed | 3 | 17 | 0 | 20 |
| Halifax | 39<br>(includes 8 mobiles) | 13<br>(includes 5 mobiles) | 3 | 10 | 0 | 20 |
| TOTALS | 1687 | 199 | 45 | 157 | 4 | 982 |

Total dollar damage for the state $77 million.

TABLE 1. NORTH CAROLINA DAMAGE, INJURY & DEATHS NOVEMBER 28, 1988 TORNADOES

## CHAPTER 2 - METEOROLOGICAL ANALYSIS

The tornadoes struck at a time of year that is rare for tornadoes. In records dating from 1916, November and December are the months having the fewest number of tornadoes in North Carolina. Only twelve tornadoes have been reported in North Carolina during November for the period 1916-1987. No fatalities were recorded. For the same period of record, eight tornadoes were recorded in December. One fatality was reported in 1942. In the 72-year recorded history of North Carolina tornadoes, only one tornado was reported in Wake County in both November (1966) and December (1942).

In the days preceding the event, a series of short wave troughs in the westerlies traversing the United States had developed and intensified into a long wave trough over the middle sections of the country. In response to this, a cold front moved east across the Great Plains leading a dry continental polar air mass into the Mississippi River Valley by Saturday evening, November 26th. The cool dry air continued moving east, and by nightfall late Sunday had reached the Appalachian Mountains, ready to spill over and across North Carolina during Sunday night.

This cold front had produced severe weather as it crossed the southern plains and southern Mississippi River Valley. In the 24-hour period ending 0400, Saturday the 26th, the National Severe Storms Forecast Center (NSSFC) had collected 64 reports of severe weather, including tornadoes, over portions of Oklahoma, Texas, and Arkansas. In the following 24-hour period ending 0400, Sunday the 27th, 14 occurrences of severe weather had been reported over Louisiana, Mississippi, and Alabama. However, from about 1900 Saturday until 1900 Sunday the 27th, no severe weather had been reported as the cold front swept east from the Mississippi River Valley to the southern Appalachians.

On Sunday, warm and humid air was brought into eastern North Carolina by brisk southerly winds off the eastern Gulf of Mexico and off the Gulf Stream east of Florida. Temperatures in the 70s and dew points in the 60s were common that afternoon and evening despite extensive cloud cover. At Raleigh, temperatures on the 27th averaged 21 degrees above normal.

### Upper Atmosphere

At 1900, Sunday evening, the 27th, two jet streams over the Southeast could be identified from radiosonde data and satellite imagery (Figure 2).The polar jet stream associated with the intrusion of colder air extended from Texas to western Tennessee and northeastward to southern Ontario, Canada.

A subtropical jet stream, as depicted by a sharp moisture gradient in the GOES moisture channel imagery and by strong vertical wind shear near 40 thousand feet (200 mb) in available sounding data, streaked across the Gulf of Mexico to the Gulf Coast near Mobile, northeastward to the vicinity of Raleigh, and off the Delmarva Peninsula over the Atlantic.

Between the two jet stream axes, analysis of the 300 mb level at 1900 the 27th revealed a diffluent wind pattern with wind speeds of 70 to 90 kts across the area. At the 500 mb level, Nested Grid Model (NGM) output from the National Meteorological Center (NMC) showed a vorticity minimum moving into North Carolina from the southwest. The 12-hour projection from the NGM, valid at 0700 the 28th, implied no increase in vorticity at 500 mb during that night.

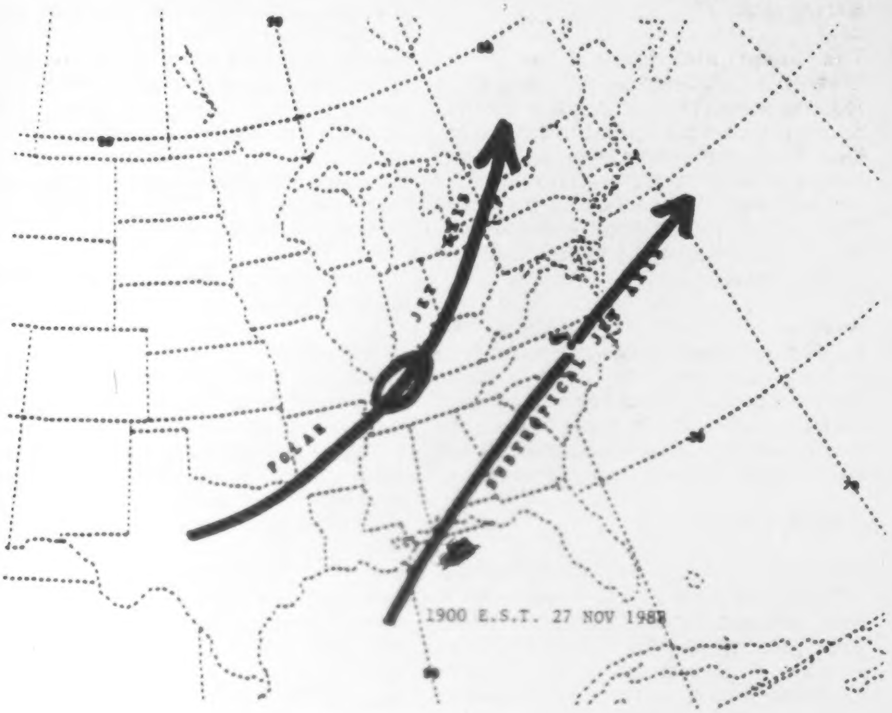
### Lower Atmosphere

Data from the network of radiosondes over the Southeast at 1900 the 27th showed a

FIGURE .

## LOCATION OF JET STREAM

1900 E.S.T., NOVEMBER 27, 1988


POLAR
JET AXIS
SUBTROPICAL
JET AXIS
1900 E.S.T. 27 NOV 1988

very moist, nearly saturated air mass east of the Appalachians. Precipitable water values approached 300 percent of normal. At Greensboro, NC, less than two degrees Celsius separated temperature and dewpoint profiles from the surface to above the 600 mb level.

The lower atmospheric winds at Greensboro, Charleston, SC, and Cape Hatteras veered 30 to 40 degrees, south to southwest, from the surface to the 850 mb level. Through the same layer, wind speed increased with height from 10 knots to about 50 knots. Above the 850 mb level to 700 mb, little vertical shear was observed with winds averaging 50 to 70 knots from the southwest.

Analyses of atmospheric stability at 1900 the 27th detected an axis of maximum instability extending from Georgia northeastward across central North Carolina to the Delmarva Peninsula. Along that axis, the K-index was 36, total-totals reached 49, and the Showalter Index dropped to zero.

### Surface Weather

Analyses of surface weather parameters at 1900 and 2200 the 27th (Figures 3 and 4) revealed a cold front moving across the Appalachians into Virginia and the Carolinas. At 1900, a discontinuity in the temperature/dewpoint field was analyzed as a warm front, extending eastward of the cold front from the Georgia-South Carolina border across the southern piedmont of North Carolina, over Raleigh and the northern coastal plain to southeastern Virginia. The cold front separated air with 70-plus temperatures and 60-plus dewpoints to the east from air with temperatures and dewpoints in the 50s to the west.

By 2200, the warm front had moved northward to Virginia. Following a brief shower that left only a trace of rain, the temperature at Raleigh warmed from 61 to 69 degrees between 1900 and 2200.

That Sunday evening, very few showers occurred over central eastern North Carolina (east of Greensboro-Charlotte to the coastal plain). To the west, several heavy showers and isolated thunderstorms had occurred, moving rapidly from southwest to northeast at speeds of 50 to 60 mph, from northern Georgia across the foothills and western piedmont of the Carolinas into Virginia. These occurred in two or three small waves of activity during the course of the evening. Very heavy rain was reported with some of the cells as they crossed the area, but no severe weather was observed nor inferred with any of the showers and thunderstorms that evening.

### Storm Evolution - Satellite Imagery Interpretation

GOES moisture channel imagery Sunday evening had depicted the subtropical jet stream over central North Carolina, running southwest to northeast. Several small perturbations, identified by brighter gray shade enhancement, could be seen by Raleigh forecasters moving along and just to the left of the jet axis during the course of the evening.

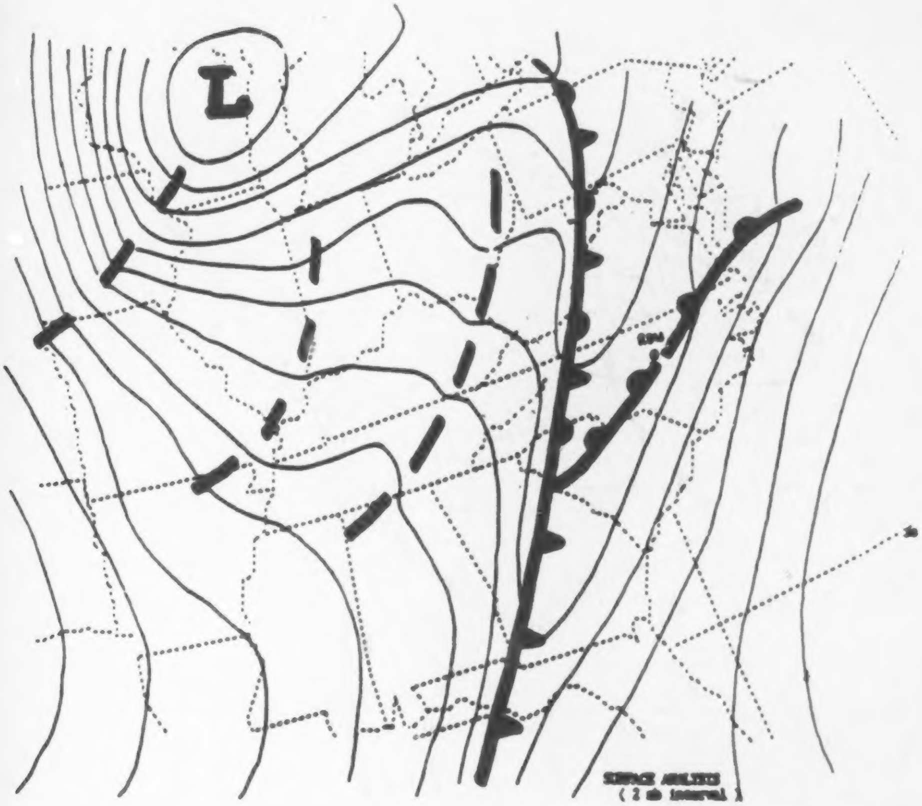
One of these perturbations, or waves, passed over the western Carolinas between 2000 and 2300. Following this wave, judging from the significant darkening on the moisture channel image, drier air aloft was brought into the area from northern Georgia. However, the radiosonde data from Athens, GA (AHN) at 1900 the 27th revealed no dry slot aloft.

Immediately following this area of apparent drying aloft, another perturbation that seemed to originate in the vicinity of Mobile, AL at about 1800 the 27th traversed the same area. This eventually coincided with the tornadic storm over Raleigh at 0100.

The area of enhanced cloudiness that eventually evolved into the tornadic storm came across western South Carolina into the North Carolina Piedmont between 2200 and 2300. The 2300 standard enhanced infrared

FIGURE 3

SURFACE ANALYSIS
1900 E.S.T., NOVEMBER 27, 1983 (ISOBAR SPACING IS 2 MB)


L
SURFACE ANALYSIS
( 2 mb interval )

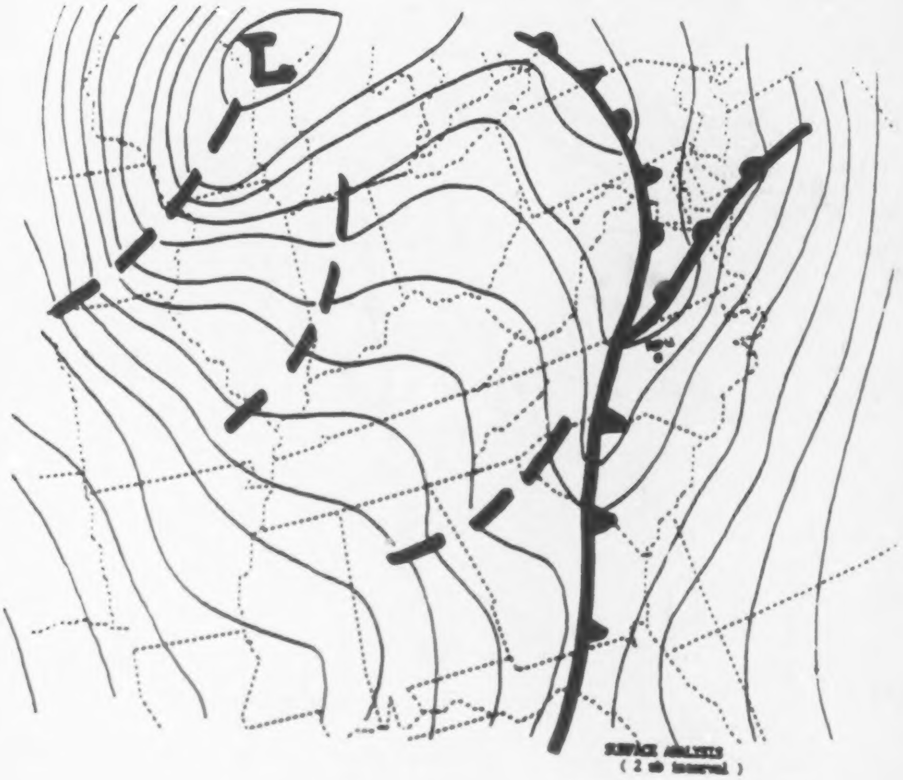
1900 E.S.T.  27 NOV 1988

FIGURE

SURFACE ANALYSIS

2200 E.S.T., NOVEMBER 27, 1988

(ISOBAR SPACING IS 2 MB)


L
SURFACE ANALYSIS
( 2 mb interval )

2200 E.S.T. 27 NOV 1988

imagery (MB curve) available to Raleigh forecasters showed a broad area of Step 5 (light gray) enhancement corresponding to cloud tops in the range of 30 to 35 thousand feet. One picture element (pixel) approximately over Stanly County in the southern piedmont showed Step 6 (dark gray) enhancement indicating overshooting cloud tops in the 35 to 38 thousand feet range. Step 6 enhancement was not unique to this group of cells during the course of the evening, but did indicate an overshooting top with this particular wave.

By 0000, the overshooting top, Step 6 enhancement, had grown in areal extent to 50 miles southwest of Raleigh. The overshooting top was located on the southern flank toward the central portion of a cluster of convective cells. At this same time, a line of warmer-topped clouds could be seen extending approximately from the area of the overshooting top southward into South Carolina. The satellite imagery and surface observations showed moist low level inflow was entering the system from the south. The 0000 WY enhanced infrared imagery, not available to the forecast office, showed what appeared to be two separate anvils oriented in different directions. This would imply diffluence aloft. At 0300, the overshooting top continued to expand in areal extent.

Since satellite imagery is not available to forecast offices until 25 minutes after picture taking time, all imagery after 0030 were not available to the Raleigh forecast office prior to the 0100 initial occurrence of the tornado.

At 0100, the overshooting top expanded dramatically and cooled to Step 7 (black) enhancement, as it moved over the Raleigh area. This level corresponded to 40 to 42 thousand feet altitude, the level of the subtropical jet.

At 0131, satellite imagery showed rapid warming (lowering) of the cold cloud tops. The areal extent of the overshooting tops decreased. A flanking line to the south, containing warmer topped cells, continued and was particularly evident in enhanced infrared imagery (EC curve).

### Storm Evolution - Radar Interpretation

The Raleigh local warning radar was inoperative. However, the tornado formed four miles from the radar site, entirely within the ground clutter pattern. Thus, it is unlikely radar images normally provided by the local warning radar at Raleigh would have alerted forecasters to the formation of the tornado. Throughout this episode, information from Volens and Wilmington radars did not provide sufficient evidence to issue a tornado or severe thunderstorm warning.

Radar observation reports, photos of radar scopes, and traces of radar echoes prepared in real-time were examined for the radars located at Volens, VA (VQN) and Wilmington, NC (ILM). From this information, station logs, and interviews with people on duty, the following was determined:

2300 - 0100

At 2325, ILM reported a cell with a maximum top of 35,000 feet located over the border of Stanly and Anson Counties in south central North Carolina. This cell was moving northeast at 50 mph. At 0028, VQN observed level 3 intensity with tops below 35,000 feet, about 30 miles west of Raleigh. Cells were embedded in an area moving east-northeast at 35 mph, while the individual cells were moving northeast at high speeds of 45 mph.

0100Z - 0200

At 0103, VQN transmitted a special radar observation. A few minutes earlier, the radar operator had called this information to the Raleigh lead forecaster. The tropopause was reported to be 46,900 feet at Greensboro. The radar operator reported a maximum top of 45,000 feet over Raleigh and the cell showed level 4 intensity (very strong) to 16,000 feet, thus satisfying the criteria for a special observation (convective echoes with tops within 5,000 feet of the tropopause). The cell was moving northeast at 50 mph.

At about 0116, the radar observer responded to a call from the Raleigh forecaster, telling him the cloud tops had lowered and the intensity decreased.

At 0134, VQN transmitted a regularly scheduled hourly observation, showing the tornadic cell tops had lowered from 45,000 to 37,000 feet and the cell was at intensity level 4. Movement remained northeast at 50 mph. Apparently the intensity weakened slightly between 0103 and 0116, and then intensified back to level 4.

At 0145, ILM radar displayed a maximum top of 38,000 feet with intensity level 4 extending to 22,000 feet. The tropopause height at Charleston, SC was 45,500 feet, at Greensboro, NC 46,900 feet, and at Cape Hatteras, NC 47,100. The maximum top was below the criteria to issue a special observation, and therefore, none were issued by ILM from 0030 to 0130.

## Discussion

When a polar and sub-tropical jet stream are in close proximity, they can form an environment favorable for upper level divergence to develop between them. Divergence aloft is a concept recognized to be a significant mechanism in triggering convective instability. From examining satellite and radar observations, one may conclude that this system "explosively developed" from 0000 to 0100. Convective instability apparently dramatically increased during this time.

At about 0134, VQN radar reported that the maximum top of the tornado producing cell lowered by 8,000 feet. At about the same time, satellite imagery indicated rapid warming (lowering) of the cloud tops. The collapse phase of a storm is often followed by severe winds due to strong downdrafts/downbursts, and possible tornadoes. This stage is marked by a dramatic weakening or overall collapse of the main updraft and enhanced downdrafts. On radar, this is recognized by lowering storm tops, and reduction in both the maximum echo intensity aloft and the vertical extent of the updraft. The only significant feature in the radar signature from VQN was the lower maximum tops. The echo intensity aloft did weaken for a short time, but then regained intensity back to level 4.

Most of the satellite and radar clues discussed here were either unavailable to the Raleigh forecast office, or did not become available until after damage was already reported. Furthermore, it is questionable as to whether these clues, determined by after-the-fact studies, could have been quickly and easily identified during any unexpected severe weather event. And, these same clues would be interpreted differently if no severe weather had been reported . No conclusive severe weather clues were available to the Raleigh forecast office prior to the tornado.

## CHAPTER 3 - NATIONAL WEATHER SERVICE OPERATIONS

There was awareness through the weekend by both Raleigh forecasters and NSSFC about the possibility of severe weather accompanying the eastward moving system. However, during the afternoon and early nighttime hours on Sunday leading up to the severe weather, the system had produced none. The Raleigh evening shift continuously monitored the weather for severe activity. By shift change, none had occurred and North Carolina was not in any NSSFC predicted threat area. Even so, the midnight shift radar operator at the Volens VA network radar station was called shortly after midnight to insure he was aware the Raleigh radar still was out of service.

Approximately the first hour and ten minutes of the midnight shift at Raleigh were spent mainly on developing the complex upcoming forecast. During this time, two time-lapse loops, one from the radar at Columbia and the other from Volens that had been maintained by the evening shift were kept current with at least one picture from each radar added to the loop. There was a coordination call with Volens about a thunderstorm approaching the airport, and a thunderstorm was in progress at Raleigh at 0100 (which is also synoptic observation time).

The upcoming forecast package to be issued by 0400 presented large problems. Showers and thunderstorms would be ending from the west during the early part of the first period. Steady or falling temperatures were expected to occur across much of the state during the day. A gale warning was in effect on the coast. The first measurable snowfall of the season was probable in the mountains. At the time the first report of severe weather came in, the Raleigh lead forecaster was coordinating a frost warning for the central and south coast for the coming night. The changing weather pattern was a challenge for the aviation forecaster to keep terminal and transcribed weather broadcasts (TWEBS) current and to prepare for the upcoming forecast.

There was no tornado or severe thunderstorm watch in effect when the tornado hit Raleigh, NC at 0100. Attachment 1 chronicles NSSFC operations before and during the onset of the event.

The first damage reports were received on North Carolina NAWAS about 0115. In about two hours, all of the severe weather in the WSFO Raleigh area of warning responsibility had occurred. During that time, the three people on duty received an almost constant flow of severe weather reports and inquiries for weather information. At the same time, a special weather statement, two tornado warnings and a tornado watch were issued.

Raleigh issued the special weather statement at 0135. A tornado warning was issued for Franklin County on NOAA Weather Radio (NWR) at 0145 (valid until 0215) and on AFOS at 0148. The tornado entered Franklin County about 0120 and exited about 0155. A tornado warning was issued for Halifax County via AFOS at 0203 (valid until 0230) and on the NWR at 0206. The tornado entered Halifax County about 0205 and exited about 0226. No warnings were issued for Wake, Nash, Northampton, Pamlico and Hyde Counties where tornado damage occurred. A tornado warning was issued by WSO Cape Hatteras for Dare County at 0550, one minute after the tornado ended. A watch was in effect when the tornadoes occurred in Nash, Halifax, Northampton, Hyde, Dare and Pamlico Counties. No watch was in effect for Wake and Franklin Counties.

During this event, the radar at Raleigh was not operational. This made it necessary for the WSFO to coordinate with Volens when making decisions on possible warnings after damage reports were received. This type of coordination was done several times. Attempts to dial into the Volens radar proved to be fruitless with at most only two or three pictures being received. This was a time consuming duty which produced little benefit at a critical time in the warning process. The volume of incoming information overwhelmed the personnel on duty. Telephone logs were not maintained because of the extreme activity. Frequent interruptions due to incoming reports and attempts to coordinate with State agencies, local agencies, and other NWS offices prohibited response to every piece of information.

The SWIS equipment at Raleigh worked properly. Though several features in satellite imagery discussed in the previous chapter were recognized by the forecaster, as the tornado developed, none could be considered unique to severe weather prior to the event. Overshooting tops had been seen in other convective cell groups yet no severe weather developed from these cells. This feature is not unique to tornadoes and can be accompanied by only heavy rain, as was expected during this night. The overshooting feature seen in the 0100 picture would not have been available to the operational forecaster until 25 minutes past the hour.

A Satellite Interpretation Message transmitted at 0038 by the Kansas City Satellite Field Service Station, called attention to a strong cell 50 miles northeast of Raleigh, but did not call attention to any cells over, or approaching, Raleigh.

During the severe weather event, the two forecasters and the meteorological technician were monitoring six communication lines. These included two FTS lines (one a rollover when the first is busy), the media line, the local airport line, a special line from the FAA, and the North Carolina NAWAS. At the onset, the staff also answered the daytime administrative line in hopes of gaining additional information. No calls were made or received on the Virginia NAWAS.

These lines of communication put an almost constant demand on the staff's time. However, each of these lines is necessary to severe weather operations. County sheriff departments and spotters have been given the media line to report severe weather. Coordination calls from Volens and NSSFC were received on the FTS system. Concern by local airport officials came in over airport and FAA telephone lines. And of course, most severe weather reports and contact with the state warning points were on NAWAS.

The NOAA Weather Wire Service (NWWS) was not operational at the state warning point because of prior existing problems at this location. Thus, additional time was needed to pass on information on items that normally would require a brief communication via NAWAS telephone. Also, temperature, dew point, and wind information were not available automatically. This put an extra burden on the observer when taking observations, requiring the observer to leave the office to read equipment and to call the FAA tower for wind information. It also made it difficult to know the maximum wind speed when the thunderstorm passed over the airport. Attachment 2 is a chronology of events at WSFO Raleigh.

At WSO Wilmington, NC, the staff on the midnight shift, when the tornadoes occurred, was the normal complement consisting of one meteorological technician. His job was to handle multiple observing programs, dissemination, and warning responsibilities. With no positive indication of severe weather at the beginning of the midnight shift, no extra personnel were held over from the evening shift.

Later, when there were indications of a severe weather threat, the man on shift decided to "tough it out," partly because of the reduced number of people available to work at WSO Wilmington NC, and partly because of the known concern to keep overtime costs down. The staff available for call-in was short, with two people on leave and one having recently resigned. During the height of the severe weather, the one person on duty had difficulty handling the workload.

In Virginia, a tornado warning was issued by WSO Norfolk at 0310 (then corrected at 0314) valid to 0415 for Southampton and Isle of Wight Counties and the City of Franklin. The warning verified for all three locations. The warning was based on radar and past history of the tornado activity. A tornado watch was in effect for the above locations from 0215 until 0600. No watch or warning was in effect for the tornado that hit Brunswick County, VA about 0130.

## CHAPTER 4 - DATA ACQUISITION

As stated earlier, the Raleigh local warning radar was inoperative. The WSFO staff went into the backup mode, operating via a dialup connection to Volens, VA. In dial backup mode, continuous images of the Volens radar cannot be received. A telephone call is needed for each image. The backup line is not dedicated, and WSFO Raleigh had to compete with other (external) users of the radar in order to receive images. Dial up to VQN was completed at 0030 and 0045, but no additional connections could be made until 0300. In contrast, WRAL-TV went on the air at 0212 and, with a dedicated telephone line, was able to broadcast the real-time images continuously with a voice-over. The TV meteorologists, working with statements provided by the NWS, were able to identify the radar features associated with the storm and to keep listeners informed.

With few radar images available to WSFO Raleigh, the staff relied on telephone (voice) communications to determine what was happening and why. The lead forecaster called the Volens observer immediately after getting the first damage reports at about 0115 over NAWAS, and then from a power company meteorologist. The radar observer said the cell intensity had lessened in the last 15 minutes (down 1 VIP level) and that the tops had lowered by approximately eight thousand feet from a maximum height of 45,000 ft. This observation was interpreted by the forecaster to mean the storm was weakening and whatever had caused the damage probably was over. However, incoming telephone calls with damage reports and requests for information continued. At 0135 one of the off-duty WSFO forecasters called with a report of a possible tornado. At that time, still trying to corroborate the continuing event with real-time observations, the lead forecaster directed the aviation forecaster to concentrate all efforts on the severe weather problem.

The temperature/dew point/wind readouts on the observation console were not operating because a telephone line had been cut several weeks before. The wind readings were received from the FAA tower via telephone calls; but the observer did not know the maximum wind speeds when the thunderstorm passed over the airport at 0100. Temperature and dew point were read manually directly from the sensors outside of the office.

Between 0030 and 0100, just before the tornado hit Raleigh the lightning monitor at NSSFC indicated a significant clustering of strikes associated with a Radar VIP level 4 cell. This was the cell near Raleigh that was reported by the Volens radar operator, and also detected by the Wilmington radar. However, the lightning information was not available to the WSFO, since the AFOS product is generated only once an hour on the half hour, and reflects only the previous 15 minutes of data.

The WSO Cape Hatteras network radar failed at 0330 while the WSO was in a tornado watch area. The electronics technicians were called in and the radar was returned to service at approximately 0430. The commercial power failed during the storm (approximately 0500) for about 30 minutes, taking down both the radar and AFOS. Recovery of the WSR-57 radar after power loss takes about 15 minutes. This delayed the Cape Hatteras issuance of the tornado warning for Dare County.

### Radar Outage at WSFO Raleigh

The Raleigh local warning radar had failed at 0839 on November 20 and the electronics technician was notified at 0845. Troubleshooting began at 1000. The Pulse

Forming Network (PFN) was identified to be defective, and a new part was ordered from the National Logistics Support Center (NLSC). The new part arrived overnight. However, upon inspection, the electronics technician found that the new PFN was different physically from the old one. The area electronics supervisor (AES) found out from National Weather Service Headquarters (NWSH) that a modification kit was needed in order to install the part. Neither the AES nor Eastern Region Headquarters electronics personnel were aware of the modification requirement.

The mod kit was sent from NLSC and instructions for installation were forwarded from NWSH. The new parts were installed on the 22nd, but the radar failed to come up to full power. The AES suspected that the magnetron needed replacement. A new one was placed on emergency order with NLSC. The new magnetron was received on the 23rd at 1545 and installed immediately by the AES. However, the radar still could not be brought to full power. The AES sought advice from NWSH, but was not able to reach the radar electronics expert there. The AES decided not to leave the radar on with less than the proper signal strength since it would represent a distorted signal to users, and could lead to erroneous interpretations by forecasters. November 24 was the Thanksgiving holiday. NWSH and Raleigh electronics personnel were on leave Friday, November 25th. However, the AES called the WSFO to monitor the weather situation to determine if emergency maintenance was needed. Since the Raleigh radar is not a network radar, barring any major predicted weather events, maintenance is deferred to normal working hours. A meteorologist called the AES on Saturday afternoon. There was a question of some weather east of Raleigh and the meteorologist wondered if a box that came in contained needed parts. The AES responded no parts were on order. The radar remained inoperative.

On Monday, November 28, after the tornado outbreak, and after consulting NWSH, a new PFN was ordered, along with a new Thyratron Pulse driver. The parts were received on Nov. 29, installed, and the radar returned to operation by 1700.

## CHAPTER 5 - DISSEMINATION

### Emergency Broadcast System (EBS)

Under a 1977 arrangement, all radio and television stations within a designated area monitor a Common Program Control Station (CPCS-1) for EBS messages on a voluntary basis. NWS warning offices deliver watches/warnings to the CPCS-1 stations by various methods. The CPCS-1 stations then activate EBS. After receipt of the warning message, the EBS tone alerting process takes approximately 25 seconds. After the series of activation tones are finished, the CPCS-1 station may either read the watch/warning or play a recorded message provided by the NWS. Stations monitoring the CPCS-1 station may, at their discretion, play the CPCS-1 station signal directly on their station, copy the message and use their own announcers, or take no action at all.

The designated operational areas decide for themselves what types of messages warrant EBS activation. Some areas may wish to activate for all warnings; some activate for only tornado warnings and tornado watches.

There are two EBS operational areas covering the area of the Raleigh tornado. WQDR-FM in Raleigh is the CPCS-1 station for 11 counties including Wake and Franklin Counties. WTRG-FM, whose transmitter is in Rocky Mount but with studios in Raleigh, is the CPCS-1 station for six counties including Nash, Halifax, and Northampton Counties. These CPCS-1 stations will activate EBS for the first tornado watch of the day, tornado warnings, and severe thunderstorm warnings issued under tornado watch conditions. They do not activate EBS for severe thunderstorm watches/warnings except as noted above.

Each time the Raleigh WSFO wishes to activate EBS through WQDR-FM, they must dial a special telephone number to reach a digital recorder and follow very strict recording procedures. Once the recording is finished, they must listen to the recordings and if it is satisfactory they hang up and call WQDR-FM to alert them to the message. When Raleigh wishes to activate EBS through WTRG-FM, they make a direct telephone call and they must wait while station personnel get ready and finally record the message.

The Survey Team visited WQDR-FM and WTRG-FM. WQDR-FM did not activate EBS for the Franklin County warning nor did WTRG-FM activate for the Halifax County warning. Both stations receive hard copy warnings from the Associated Press (AP) and do not subscribe to the NWWS.

WQDR-FM received the tornado warning from AP for Franklin County in a prompt manner. However, they chose not to air the warning because the NWS had not followed the usual procedure of recording the warning into the WQDR digital recording equipment. The WSFO staff felt they could not take the extra time necessary to make the calls, but knew that the message had been sent via NWWS and AP, and the message contained a statement requesting EBS activation. WPTF-AM, operating from the same facility as WQDR, began receiving storm damage reports from listeners at 0106 and broadcast the information as it was received. At 0149, the WPTF announcer brought the Franklin County warning to the attention of WQDR-FM. At 0202, the WPTF announcer interrupted the network news to pass along the Franklin County warning.

WTRG-FM received the 0135 special weather statement from the Raleigh WSFO via AP high speed circuit. They also received via AP, Tornado Watch No. 513 which was transmitted by Kansas City at

0524 and by Raleigh along with the Areal Redefining Statement at 0535. WTRG-FM did not receive from AP the 0200 warning for Halifax County nor Tornado Watch No. 512 sent by NSSFC shortly after 0200.

WSFO Raleigh did not make the calls to WQDR nor WTRG for the respective warnings nor to WQDR for Tornado Watch No. 512. They did call WTRG at 0245 for Watch No. 512 and at 0545 for Watch No. 513.

**NOAA Weather Radio (NWR)**

There are nine NWR transmitter sites in North Carolina. WSFO Raleigh serves three of these transmitters from their office. Each transmitter is serviced by a separate program console.

With regard to the Raleigh tornado of November 28, 1988, because of the time of day, few people were listening to NWR for information. At 0135, a special weather statement was put on the air and at about 0145 the tornado warning for Franklin County was placed on the NWR with tone alert. At about this time, a fireman who lived in the tornado path just northwest of Justice, NC said: "At about 0145, my scanner went off and I heard the chattering about a tornado. I immediately turned to NWR on my scanner but didn't hear anything about a tornado. I heard it (the tornado) coming and got my wife and son into our center hallway. It was all over in two minutes."

The Halifax County tornado warning was placed on NWR with tone alert at 0206. The Survey Team tried to find someone to confirm receiving this warning via NWR but were unable to find such a contact. At 0225, Watch No. 512 was tone activated for the Durham and Tarboro transmitters.

As previously mentioned, neither EBS station (WQDR-FM and WTRG-FM) was tuned to NWR.

**NOAA Weather Wire Service (NWWS)**

WSFO Raleigh drove the NOAA Weather Wire Service, and most subscribers received the messages. The state warning point at the North Carolina Highway Patrol Communications Center had not received NWWS traffic since late in September because of an internal problem. They decided not to fix the problem, but rather to wait for the new satellite NWWS system. The phone company has no record or any reports of weather wire outages prior to or during the tornado. An outage in Nash County appeared to be a local problem due to the approaching tornado. The full extent of the outage was unknown, but did not appear to be widespread.

**Division of Criminal Investigation (DCI) Computer System**

The State of North Carolina's Division of Criminal Investigation operates a statewide computer system, DCI. This computer system is tied into the various law enforcement agencies throughout North Carolina.

DCI carries NWS watches, warnings, and other selected products. However, the message transfer from NWWS to DCI is not automatic, although the NWS had discussed the need for automation and the availability of computer software for this purpose. The employees of the Highway Patrol, State Warning Point, must type the information into the computer system and then send it to the appropriate area.

The Raleigh tornado resulted in a number of power surges which disrupted computer communications for a short period. The Division of Criminal Investigation computer system did not receive the special weather statement, Franklin County tornado warning, or Watch No. 512. They did receive the warning for Halifax County and Tornado Watch No. 513 and this information was made available via the DCI computer.

### Associated Press (AP) Wire Service

The Associated Press offers high-speed, 1200 baud service, and slow- speed 56 baud service in North Carolina. Totally, they service 160 radio and television stations along with 56 newspapers.

Subscribers to the high-speed circuit may get their information in one of two ways. First, they may have a direct tie-in to a satellite dish or they may get a feed from a dish in the area via telephone lines. In Raleigh itself, most subscribers are fed from AP's dish and computer system.

At 0108, November 28, 1988, AP lost power. The loss of power took their computer down. They had just one person on duty who was not able to restore the AP computer until 0241. This means those stations served directly from the AP office via either the high speed or slow speed circuit would have received no information. Those stations served directly (satellite dish) would have received all of the information from the NWS via the Family of Services circuit.

### Local Media

The Survey Team made personal visits to three radio stations, WRAL-TV (TV-5), and talked with reporters from the Raleigh News and Observer.

Each radio station began receiving feedback about wind damage in north Raleigh within ten minutes of the initial tornado touchdown. Within a short period of time, they knew something significant had happened and they kept their lines open to the public. One station had a part-time announcer working the night shift. At 0245, the NWS telephoned this station with Watch No. 512, but the announcer did not know how to activate EBS.

Normally, WRAL-TV is off the air between midnight and 0500 on Monday mornings. The station did go off at midnight, but later a photographer from the news department who lived in the first area damaged reported the storm to the station. The station went back on the air. Two staff meteorologists arrived at the Station by 0212. One of the first things they did was to connect into the NWS radar at Volens, VA. Their equipment allowed them to stay connected to the radar signal and receive continuous updated pictures. Thus, they were able to show the storm cell on the air through the remainder of the event.

## CHAPTER 6 - COMMUNITY PREPAREDNESS

Following the March 28, 1984 tornado outbreak across the Carolinas, one of the recommendations was to establish a Warning Preparedness Meteorologist position at WSFO Raleigh. The position was filled the following year.

With the addition of a formal warning preparedness position to the WSFO Raleigh staff, the Area Manager was able to direct a very effective preparedness campaign. In three short years, there has been a marked turn-around in preparedness activities and knowledge throughout North Carolina. Dr. James McDonald, Director of the Institute for Disaster Research at Texas Tech University, is quoted, in a Raleigh newspaper interview, as saying, "I think over the years through the watches and warnings......we have pretty well conditioned people to know what to do. People can recognize a wind storm and just kind of instinctively know what to do because they've heard it so many times over the media."

On November 28th, as the storm approached, a strong driving rain along with thunder and continuous lightning awakened and/or alerted many people. The public knew something was wrong and became very concerned when they heard the often talked about freight train sound. Fortunately, in this case nature's advance warning provided sufficient response time for many people to go to the safe places they heard of so many times during the past three years.

Anglia Bowling, a school teacher, said, "at five after one, I was awakened and knew that I wanted to get into the bathroom. I made it as far as the hallway before the roof went off and the building began to sway." Ms. Bowling also said, "Many people who I talked to knew to go to the hallways." When pressed about how she knew to do this, she said, "it was through preparedness materials used to teach children at school."

Shannon Gilleland, who lives near the intersection of 401 and 98 in Franklin County said, "A few years ago, our family decided the safest place for us to go in the event of a tornado would be the garage level of our split level home and kneel near the stairwell. That night, Daddy had left a window open in the bedroom because it was sort of warm. When the wind noise started, I pulled the covers over my head and could feel the house start to shake. Daddy yelled for us to go to the garage, which we did. We stayed there for a couple of minutes until the noise went away." Their home sustained severe damage but no one was injured.

Warren Boone, Assistant Fire Chief, Justice, NC stated that, "My scanner came on saying there was a tornado coming. I took my family to the crawl space under our mobile home and in a matter of seconds our home blew away. No one in my family was injured."

Whit Hayes, a barber in rural Franklin County, has an interesting story. "My wife and I were in bed when my son woke us at 0125 saying there was chatter on the scanner about a tornado in Raleigh heading northeast. I knew we didn't want to stay in our mobile home and I didn't want to lay in the culvert because I didn't want to risk playing with a snake, so we immediately got our car and drove up the hill to my barbershop. My wife didn't feel the shop was too safe because it was just one big room. We had sold our house next door to the barbershop but knew the people were not at home and since I still had a key we went into the hallway in that house. At about 0145 or so, the noise got real bad. When the noise quieted down, we got back in the car and drove down the hill to where our mobile home had been but it was no longer there.

We knew what to do because we paid attention to what the National Weather Service told us to do after the 1984 tornadoes. We appreciate your teaching us what to do. Keep it up."

In Franklin County, emergency management officials told the Survey Team that occupants of most of the 23 mobile homes damaged or destroyed knew to evacuate as the tornado approached. All those who evacuated were not hurt. There were some injuries but no deaths to those who remained in mobile homes.

In situations like the Raleigh tornado, without question, the preparedness activities saved many, many lives. Dick Clayton, Emergency Management Coordinator for Halifax County, told the Survey Team, "Please relay to Dennis Decker's (Raleigh Warning Preparedness Meteorologist) boss how much we appreciate the help that he had given us in the preparedness area. We wish he didn't have to work so many shifts so he could do even more."

During the past three years, there were ten formal SKYWARN training sessions in Franklin, Nash, Halifax, and Northampton Counties. The significant preparedness contacts within Wake County included not only formal SKYWARN sessions, but also safety presentations to schools, service organizations, hospitals, churches, scouts, police, fire and rescue, and utility companies. In addition, since the 1984 tornado outbreak, there has been an annual Statewide Tornado Awareness Week late each winter. These campaigns consisted of mailing awareness packets to news media, police, fire and rescue organizations as well as schools. Statewide tornado drills, along with numerous media interviews, were also a part of the Awareness Week activities.

The Raleigh warning preparedness meteorologist kept in contact with the "hams" by participating in Statewide Amateur Radio Relay League's (ARRL) weekly discussions. On such occasions, all repeaters throughout North Carolina are tied together.

# CHAPTER 7 - IMPLICATIONS FOR MODERNIZATION

Several features of this disaster are significant in view of the NWS modernization and transition plans. Staffing patterns are *major issues of the NWS modernization*; and the Raleigh tornado outbreak allows us to validate or challenge these as we finalize the National Transition Plan. Keys to the resolution of personnel efficiencies and effectiveness are the technology replacement programs, and support for some systems yet on the fringes of budget and transition planning. These points are discussed below.

## STAFFING

First, the contribution of NWS disaster preparedness activities to the prevention of deaths and injuries cannot be overstated. The North Carolina outbreak provided dramatic proof of the need for such activities, as people were able to take effective actions even when surprised by the tornado.

The backbone of disaster preparedness in the current NWS structure is made of the MICs and OICs of the local Weather Service Offices. Several WSFOs, though a small minority, have disaster preparedness meteorologists, whose time is divided among other focal point duties and shift work. These are the main contacts for the local communities and surrounding areas both for disaster preparedness and emergency contact during weather warning situations.

The need to maintain an effective preparedness program in the future; and to ensure continuing liaison with local officials is extremely important. These links will be stressed especially as the introduction of new weather detection systems will precipitate changes to the field forecast organization.

Another major staffing issue in the North Carolina event was the ability of the staff to keep up with the tremendous workload of *public and emergency services interactions* generated during the initial storm outbreak. Even had the staff been able to identify the severity of the tornadic cell, they would not have been able to keep up with the outside communications workload.

The shift staffing at the WSFO during the outbreak (2 mets and 1 met tech) was similar to that envisioned for the future WFO. There have been some proposals to consider reducing the midnight shift staffing--the same shift during which the event occurred--to one meteorologist and one meteorological technician. With the present technology and operations, such staffing during the Carolina outbreak would have resulted in a complete breakdown of operations. Hopefully, shift staffing with the new technologies and geographical coverage will be tested fully under all forecasting conditions before final staffing commitments are made.

In order to make the two plus one staffing responsive to severe weather outbreaks in the future NWS, several things must happen: a) we must have a good, working knowledge of mesoscale meteorology as depicted by NEXRAD and satellite imagery; b) we must have the ability to integrate this information in one workstation so that we do not have to dedicate an individual to the radar while another person coordinates the outside communications and other incoming data and analyses; c) we must generate our warning messages automatically, including some automated form for NOAA Weather Radio. All of these point to the expeditious implementation, and most effective use of new technologies. A few dimensions of these technology issues are mentioned below.

## TECHNOLOGY

Paramount among the technology issues is the need for immediate replacement of the national network of radars. The poor quality of detection, the misery of maintenance with obsolescent and unavailable parts, the lack of base funds to support dedicated dial backup while radar failures are increasing in frequency and severity, are a plague on NWS operations. The NEXRAD system will afford the stability and reliability essential to our warning operations that were lacking in this episode.

The Dopplar detection capability, and high time and space resolution probably would have allowed forecasters to view the rotation and severity of the storm cell as it developed, helping to identify the event as a tornado, and giving predictive ability to the forecasters. Ground clutter notwithstanding, an advisory, watch or warning probably could have been generated before the storm struck the ground. Even if not detected a priori, certainly the F4 cell would have shown clearly as it exited the ground clutter area and moved on its long path of destruction to the northeast.

The NEXRAD modular design should make for easier maintenance. This will help eliminate the "shot-in-the-dark" trouble shooting with which we are saddled by today's obsolescent systems. In addition, the new system will allow faster power down/up operations when switching over to emergency power. At Hatteras, this timing was a factor in the delay of the warning.

On a cautionary note, the planned centralized NEXRAD parts distribution and quality control procedures will be critical to operations. A few weaknesses in the present centralized system were shown in this event, and must be corrected for all future central support systems. Further, if maintenance is to be performed under contract, response times and operational contingencies must be addressed meticulously--this in combination with the planned backup capability.

At present, NEXRAD backup--and access to DoD Radar Data Acquisition sites for primary coverage--is to be provided through a dial-up mode. As described elsewhere in this report, dial backup over non-dedicated lines proved an inadequate mode of operations during the Raleigh outbreak. Hopefully, the NEXRAD system will ensure a dedicated mode of operation for this dial-up purpose.

Other individual data acquisition systems worked properly, including SWIS, as did the information dissemination systems. Individual lines of communication also worked at the WSFO. Yet, the staff had major problems digesting the information. While station drills and written procedures may be strengthened, and additional emphasis put on maintenance of station logs, a great deal of time and accuracy in operations could be gained by combining these individual information gathering, formatting, and warning distribution systems.

The AFOS replacement, the planned Automated Weather Interactive Processing System, specifically is designed to allow forecasters access to an integrated local data base of radar, satellite, and ground truth (mesonet) data, as well as national and regional analyses and guidance. AWIPS will have interactive, overlaying, and looping capabilities that would have been invaluable to the Raleigh forecasters trying to assess the onset and import of the damage reports.

For example, given clear indicators from a NEXRAD radar of potential severe weather, it would have been much easier to interpret and analyze satellite imagery to corroborate the existence of such phenomena. This data integration would be done at the AWIPS workstation. In the future, such integrating capabilities will be essential also because of the increased resolution of time and space in the data. The satellite imagery should be available every 15 minutes on a 2 sq.km. resolution; radar updates should be available every 5 minutes at this same scale.

Envisioning this event with an AWIPS workstation, the local forecasters probably would have been in an alert mode of operations with the strong cold front moving through the area bringing a variety of weather to the state. Two other Warning and Forecast Offices downstream of Raleigh (Hatteras and Wilmington, NC) would have been handling similar responsibilities, rather than having only the one Forecast Office issuing a package for the entire state. All would have been emphasizing the forecasts for the next 12 hours, with special emphasis on the next 2 hours. The WFO forecasters would be concentrating on mesoscale depiction and prediction activities. When the severe weather precursors were recognized, the staff would have shifted to the warning mode, calling in extra help, focusing on identifying and tracking the phenomena, predicting its growth, decay and movement and predicting the occurrence of additional events.

AWIPS should give the additional processing capability to make the computations necessary for extracting the best information from the incoming data, interacting with the data, and formatting and disseminating warning products as soon as possible. At present, each of these functions and data analysis is accomplished manually in separate actions.

These are but a few highlights of the North Carolina outbreak in light of NWS plans for modernization. No doubt we will have other events as complex and demanding of our forecasting capabilities before the new systems are in place. Fortunately, though, with our vision of Modernization, we can look back critically, in order to build the best future.

## CHAPTER 8 - FINDINGS AND RECOMMENDATIONS

The NWS Eastern Region organized a disaster survey team on the morning of November 28. The Team assembled at WSFO Raleigh at 0845, November 29th, and immediately began a field survey that lasted until the afternoon of December 1st.

Team members visited damaged areas and spoke to victims of the disaster in Wake, Franklin, and Nash Counties. The team interviewed State, County, and local officials, media representatives, and NWS employees. Based on interviews and the information provided in the Attachments, the survey team arrived at the specific findings and recommendations listed below.

In summary, a general finding immediately obvious is that preparedness planning leading to public awareness; and government and individual action in this incident helped offset the limitations in NWS storm detection capabilities. Another general finding is the need to shore up the internal NWS warning process to include improved national guidance, communications, and station procedures.

**Finding 1: Disaster Preparedness**

The National Weather Service warning preparedness program resulted in many saved lives in North Carolina. The team concluded the public awareness in North Carolina of proper severe weather responses was outstanding. This awareness is directly attributable to NWS efforts.

In 1985, the Raleigh Warning Preparedness Meteorologist devoted 62% of his time to preparedness activities. During 1986, this percentage dropped to 58. In 1987, it dropped to 52% and in 1988 it fell to 48%, mostly because of prolonged vacancies and training time needed for new employees. Some preparedness activities also were carried out by the Deputy MIC in 1987 and 1988.

**Recommendation 1:**

The NWS must strive to continue the disaster preparedness activities that lead to the public awareness of appropriate responses in the face of severe weather. These training and education efforts should take place nationwide for all types of hazardous weather. The NWS must ensure time and personnel resources are available to carry out these functions.

**Finding 2: Radar Maintenance**

The Raleigh local warning radar was inoperative for an extended period of time. Contributing to the outage were cumbersome parts replacement procedures, necessitated by the scarcity of spare parts and by the need for modification kits to make new parts fit old equipment. Many obsolete replacement parts are manufactured in small quantities and therefore are controlled in their distribution.

NWS field electronics technicians must rely on NWSH advice, guidance and approval to secure and implement these controlled parts. This advice and guidance are not available outside of normal business hours.

The PFN is a controlled item that needs NWSH approval before being shipped from NLSC. It seems that during evenings, weekends, and holidays these controlled parts can be shipped by NLSC without authorization. However, there is no guarantee that the parts shipped are from the controlled stock managed by NWSH, i.e., a supply of earlier manufactured parts, or defective parts, still may be in stock. In the case of the Raleigh outage, the radar restoration was delayed because the electronics technicians were not aware that a modification kit was needed, and the part was shipped without the modification and instructions.

According to Weather Service Operations Manual (WSOM) Chapter H-50, electronics technicians at field stations are on an on-call status when emergency repairs are required in the face of severe weather. No severe weather had been forecast, so actions were deferred until normal working hours on Monday, November 28. The team finds that these procedures were followed correctly.

**Recommendation 2**

The NWS should revamp the spare parts distribution procedure to ensure controlled parts and modification kits are clearly identifiable, are quality controlled and are known to NLSC and field electronics technicians. These parts must be available at all times in case electronics technicians are required to perform emergency maintenance. Parts not included in the controlled inventory must be marked clearly, and not allowed into the controlled parts supply system. If controlled parts require NWSH approval prior to shipment, then personnel support must be available at all times in order to secure such approval.

The NWS must pursue vigorously and with no delays, the complete replacement of its obsolete network of radars. The NWS can no longer tolerate the absence or unavailability of spare parts, nor the time- consuming measures needed to maintain and operate the systems.

**Finding 3: Backup Power**

The Hatteras radar failed at critical times during the event. electronics technicians properly were called in to fix the radar. A commercial power outage caused a second failure and helped delay the issuance of a tornado warning. Power outages at WSO Hatteras are routine--sometimes occurring several times a day, even in fair weather. With the overwhelming workload, the station supervisor did not switch to emergency power before the commercial power failed. Had the station gone to backup power, the radar would have been powered down and then back up, a process that takes a precious 15 to 20 minutes during a warning situation. In retrospect, the supervisor should have asked the electronics technicians to go to backup power when they initially fixed the radar at 0430.

**Recommendation 3**

Stations should review and implement as necessary decision procedures for converting to backup power during emergency weather situations.

**Finding 4: Radar Imagery**

The tornado formed entirely within the ground clutter pattern. Thus, it is unlikely radar images normally provided by the local warning radar at Raleigh would have alerted forecasters to the formation of the tornado. Availability of local radar imagery for downstream events in Franklin, Nash and other counties would have been extremely useful in helping forecasters track the extent and path of the storm.

Radar information from the network radars at Volens, VA and Wilmington, NC were useful only to detect the thunderstorm cell. But, these systems were incapable of discerning the upstream indicators of tornado formation, or the evolution, features and severity of the funnel once it began its path of destruction.

The radar dial backup capability at Raleigh was woefully inadequate to provide the imagery necessary at that station for proper meteorological interpretation of the storms.

The radar operator at Volens told the Raleigh forecaster at about 0116 the echo tops were lowering and the intensity weakening. The forecaster on duty at Raleigh judged the storm to then be weakening and the event essentially over.

Only after receiving new severe weather reports did the forecaster realize the event was continuing. The forecaster had no radar imagery available for his own local interpretation.

It is interesting to note that earlier in the month, on November 7, 1988, tornadoes occurred at noon in Elizabeth City, NC and 30 minutes later near the city of Moyock, NC. Neither the Raleigh nor Cape Hatteras radars indicated a tornado signature and no warnings were issued. WSFO Raleigh coordinated with NSSFC during the morning, but neither thought a watch was warranted.

### Recommendation 4

The NWS must review and improve its radar backup capability to assure continuous flow of radar imagery to the responsible warning office. Dedicated lines for backup, or the prohibition of other users entering the backup comms lines should be considered.

Reiterating Recommendation 2 above, the NWS must implement without delay its NEXRAD system to afford local forecasters the ability to detect and forewarn the public of rapidly developing severe local storms such as occurred the morning of November 28.

### Finding 5: Lightning Data

The lightning monitor at NSSFC indicated a significant clustering of strikes associated with a radar VIP Level 4 cell. This was the cell reported near Raleigh by Volens radar and also detected by the Wilmington, NC radar. Lightning strike information is one of the few instantaneous indications of convective activity. However, it is only available to NWS Forecast Offices each hour on the half hour, and only reflects the previous 15 minutes of data. Thus, the lightning information would not have been useful to detect the initial tornado formation.

### Recommendation 5:

Pursuit of a lightning detection network with data available to field stations in real time should be continued. Lightning strike data in severe weather situations should be studied to determine its added value with data available from other sources such as radar and satellite. These types of studies would be enhanced by placement of lightning detection display equipment at several WSFOs in areas with climatologically frequent convective severe weather.

### Finding 6: National Center Guidance

National Center guidance provided no indication of the potential for a tornado in the Raleigh area. Prior to 0100, when the tornado first hit Raleigh, there was no watch. The NSSFC guidance in the 1400, November 27 Convective Outlook indicated thunderstorms were expected in an area including all of North Carolina. A Satellite Interpretation Message (SIM) issued at 0030 November 28th called attention to a strong cell 50 miles northeast of Raleigh. At 0128, twenty-eight minutes after the tornado began, a SELS mesoscale discussion message called attention to the cluster of thunderstorms in the vicinity of Raleigh and stated a watch was not anticipated; however, it advised that local offices should monitor the thunderstorm area as it continued east northeast toward southeast Virginia.

The national guidance data base consists of sampling the three-dimensional aspects of the atmosphere only once every 12 hours, and the sampling points are distant from each other. These sampling aspects make it difficult to capture small scale and short duration events.

### Recommendation 6:

A study should be supported by the NWS to determine what meteorological features essential for tornadoes could have been determined, in this case, from the observed data base and forecast parameters available prior to 0100 November 28th. The study should discuss what essential features could not be determined in advance of this event, and how this deficiency could be resolved, so that a more timely watch could be issued for future similar events.

A data base which includes surface observations of higher temporal and spatial resolution will provide an early awareness of significant meteorological and hydrologic events. The Automation of Surface Observing Systems (ASOS) program, which is formally funded, has the objective to provide some of this data and should continue to be supported.

**Finding 7: Communications With Law Enforcement and Emergency Management Personnel**

The National Warning System (NAWAS) voice circuitry provided the National Weather Service with the first reports of damage. WSFO Raleigh requested additional information via NAWAS. The survey team was told by several people whose homes were damaged that the first reports they received of severe weather were on scanners that picked up voice communication from law enforcement and fire departments.

**Recommendation 7:**

The NWS, where possible, should develop computer links with law enforcement and/or emergency management agencies. Where computer tie-ins are not practical, two-way communications must be established. NAWAS is most efficient for this purpose. NWS offices that already have access to NAWAS may use this circuit to request information about damage and severe weather.

The NWS should pursue having NAWAS and scanners available for monitoring at all offices with warning responsibility.

**Finding 8: Emergency Broadcast System**

The EBS was not activated by two CPCS-1 EBS radio stations. Both stations receive hard copy from AP and do not subscribe to NWWS. Neither station has a NOAA Weather Radio.

Before a tornado warning is considered to be completely disseminated, it must be transmitted on NOAA Weather Wire, placed on NOAA Weather Radio with a tone alert, given to the state warning point on NAWAS, and placed on EBS by NWS personnel. The storm, moving at 50 mph traveled a considerable distance while this was being done.

EBS activation is a very time-consuming process. Depending on which county or counties are warned, the WSFO may have to call three different radio stations. One of the stations has a recorder that is accessed via telephone using several commands. NWS personnel ensure that the message is received by playing it back using other codes. The other stations usually tape the watch or warning with differing degrees of success. It took four attempts to record the tornado watch at one of these stations.

**Recommendation 8:**

The NWS should engage in a cooperative effort with the TV, Radio and Cable industry to enhance the automated transmission of watch and warning messages appropriate for EBS broadcast, the activation of the tone alert, and the broadcast of the message. The Weather Radio Specific Area Message Encoder (WRSAME), developed by the NWS, can accomplish this automation. The NWS should vigorously encourage the media to purchase and use WRSAME.

Also, EBS stations should be encouraged to have tone-activated NOAA Weather Radios in a stand-by mode. EBS stations should be visited at least once every six months to assure EBS activation procedures are known and can be carried out by all radio station personnel with responsibility for this task. With regard to EBS activation procedures, the WTRG-FM Station Manager said, "We recognize the need for continual training on how to activate EBS and we will do our best to see that each announcer is given that training."

**Finding 9: User Receipt of Information**

NOAA Weather Wire and NOAA Weather Radio operations at WSFO Raleigh functioned normally. However, the Nash County Emergency Operations Center lost Weather Wire communications apparently due to a local line problem. The staff at Raleigh had to call information to the state warning point because they had a prior existing NWWS problem. Some subscribers to the AP wire service did not receive some watches and/or warnings transmitted by the NWS because the local AP office lost power.

The Weather Channel received the special weather statement and both tornado warnings transmitted by Raleigh. This information was received on the public product line of the Family of Services within three minutes after transmission by Raleigh.

**Recommendation 9:**

The planned use of satellite to replace landlines for NOAA Weather Wire communications should commence immediately. All users who depend on information from the NWS should be encouraged to have an other-than-telephone back-up means of receiving the information, especially a tone-alerted NOAA Weather Radio. NOAA Weather Radio should be given wide publicity. The use of telephone should be discouraged as a means of warning notification.

Additionally, it is an operational imperative to maintain multiple channels for dissemination of warning products. This would ensure that failure of one dissemination channel would not totally inhibit receipt of warnings by the news media, emergency agencies, and the public.

**Finding 10: Station Procedures**

Twenty minutes elapsed between the first reports of damage and the first WSFO Raleigh public product. The first communications from WSFO Raleigh concerning the damage, its cause, and what may yet occur was a special weather statement rather than a warning. When this special weather statement was issued, the tornado was already on the ground for 35 minutes, had done considerable damage and put people at risk along about a 28-mile path.

Before issuing the first statement, time was spent by WSFO Raleigh in attempting to obtain information by telephone to shed more light on what was causing the damage, and to determine the future movements and intensity of the convective mechanism. Most of the telephone calls were incoming. It was known that thunderstorms were in the area but it was not expected the thunderstorms would produce damaging winds. With the Raleigh local warning radar inoperative, there was no history from the radar of features that may have moved into and then out of the normal Raleigh ground clutter pattern.

Because there were no radar images available on station, the WSFO Raleigh staff had to rely on telephone communications to determine what was happening and why. A radar observation requested by phone from Volens after damage reports were received initially gave the forecaster the impression the damage was local and finished. The need for the telephone conversations plus the complete surprise of the event contributed to the 20 minutes between the initial report and the initial statement. After the initial statement was issued, the relevant additional information originated at Raleigh for wire transmission were two tornado warnings and two watch redefining statements.

WSFO Raleigh did not activate the SKYWARN spotter network. The survey team interviewed the State Director of the American Radio Relay League, who said the

NWS should feel free to activate SKYWARN anytime, day or night.

Extra NWS staff was called at Raleigh 50 minutes after the first report of damage. One extra person came in and that was one hour and 20 minutes after the first report of damage.

The full cross-utilization of the WSFO Raleigh staff was not sufficient. The meteorological technician observer was handling many operational responsibilities during the severe weather episode. Some of these responsibilities, could have been set aside or prioritized by the lead forecaster.

WSFO Raleigh did not maintain a comprehensive log because events were happening too fast to document. However, logs are of great value when attempting to reconstruct what transpired. Logs are referred to in preparing reports such as this, which hopefully, can lead to improved NWS operations. Also, logs may be used in litigation.

**Recommendation 10:**

Offices with warning responsibility must give the highest priority to getting out a warning quickly when reliable sources have reported very recent damage due to weather. Subsequent warnings and statements should provide more information as it becomes known.

Procedures need to be further developed by NWS field stations with warning responsibility, outlining station operations in surprise warning or threat situations under different staffing levels. The procedures should address such things as discontinuing routine requirements, calling in extra people, activation of SKYWARN, operation of radar, NWR broadcasting, reducing and handling incoming and outgoing phone calls, message preparation, message transmission, receipt and handling of HAM reports, maintaining a log, etc. Unscheduled drills must be periodically conducted using scenarios similar to these events.

Where possible, labor intensive efforts should be automated. Voice automation for NWR broadcasting should continue to be pursued. This is critical for stations like Raleigh that now drive three consoles, and may drive even more in the future.

The NWS should make available to field stations, a generalized log form for local adaptation. The form must make it easy for quick and understandable entry of significant information.

## ACRONYMS

| | |
|---|---|
| AC | CONVECTIVE OUTLOOK |
| AES | AREA ELECTRONICS SUPERVISOR |
| AFOS | AUTOMATED FIELD OPERATIONS AND SERVICES |
| AHN | ATHENS, GEORGIA |
| AP | ASSOCIATED PRESS |
| ARRL | AMATEUR RADIO RELAY LEAGUE |
| ASOS | AUTOMATED SURFACE OBSERVING SYSTEMS |
| AYS | WAYCROSS, GA |
| CAE | COLUMBIA, SC |
| CG | CLOUD TO GROUND |
| CLT | CHARLOTTE, NC |
| CPCS | COMMON PROGRAM CONTROL STATION |
| DCI | DIVISION OF CRIMINAL INVESTIGATION |
| EBS | EMERGENCY BROADCAST SYSTEM |
| EST | EASTERN STANDARD TIME |
| ET | ELECTRONICS TECHNICIAN |
| FAA | FEDERAL AVIATION ADMINISTRATION |
| FTS | FEDERAL TELECOMMUNICATIONS SYSTEM |
| GOES | GEOSTATIONARY ORBITING ENVIRONMENTAL SATELLITE |
| ILM | WILMINGTON, NC |
| KT | KNOT |
| MB | MILLIBAR |
| MPH | MILES PER HOUR |
| NAWAS | NATIONAL WARNING SYSTEM |
| NC | NORTH CAROLINA |
| NEXRAD | NEXT GENERATION RADAR |
| NGM | NESTED GRID MODEL |
| NLSC | NATIONAL LOGISTICS SUPPORT CENTER |
| NMC | NATIONAL METEOROLOGICAL CENTER |
| NOAA | NATIONAL OCEANIC ATMOSPHERIC ADMINISTRATION |
| NSSFC | NATIONAL SEVERE STORMS FORECAST CENTER |
| NWR | NOAA WEATHER RADIO |
| NWS | NATIONAL WEATHER SERVICE |
| NWSH | NATIONAL WEATHER SERVICE HEADQUARTERS |
| NWWS | NOAA WEATHER WIRE SERVICE |
| PFN | PULSE FORMING NETWORK |
| PVA | POSITIVE VORTICITY ADVECTION |
| RDU | RALEIGH, NC |
| SELS | SEVERE LOCAL STORMS |
| SIM | SATELLITE INTERPRETATION MESSAGE |
| SWIS | SATELLITE WEATHER INFORMATION SYSTEM |
| TPA | TAMPA, FL |
| TWEB | TRANSCRIBED WEATHER BROADCAST |
| VA | VIRGINIA |
| VIP | VIDEO INTEGRATOR PROCESSOR |
| VQN | VOLENS, VA |
| WRSAME | WEATHER RADIO SPECIFIC AREA MESSAGE ENCODER |
| WSFO | WEATHER SERVICE FORECAST OFFICE |
| WSO | WEATHER SERVICE OFFICE |
| WSOM | WEATHER SERVICE OPERATIONS MANUAL |
| WSR | WEATHER SERVICE RADAR |

ATTACHMENT 1

November 28, 1988

MEMORANDUM FOR: Fred Ostby

FROM: Steve Weiss Steve Weiss

SUBJECT: Evening Shift Chronology Leading to Raleigh Tornado 11/28/88

The following is a chronology of events in SELS during the evening shift of November 27, 1988.

2200-0200Z Strong thunderstorms were moving across extreme northern Florida and extreme southern Georgia during the first half of the shift. They were occurring within a slight risk area, and it appeared that isolated severe storms were possible during this time. The model guidance, however, indicated that the PVA and cold air aloft would lag behind the surface cold front in this region, and this scenario was supported by satellite imagery. The combination of minimal upper level forcing, pressure falls lifting rapidly away from the area and weak surface flow over northern Florida and southern Georgia suggested that the severe threat would be somewhat limited. A Mesoscale Discussion was issued shortly after 00Z to handle this situation.

Weaker convection was occurring from northern Georgia along the east slopes of the Appalachians into the Delmarva region. Radar data indicated the cells were moving around 50 kt, but other information (special statements, etc) indicated the thunderstorms were not severe.

0200-0400Z Radar and satellite data showed that the convection began to weaken over southeast Georgia. This weakening trend was first apparent in the lightning data, which indicated a decrease in electrical activity 30-45 minutes prior to any weakening on radar (AYS images at 15 minute intervals) or satellite.

To the north, the synoptic data suggested the air mass was destabilizing over the central Carolinas. Surface moisture was pulling westward from the coastal plain with mid to upper 60s dew points now into CAE and RDU. Well defined pressure rises were evident across western Georgia behind the surface cold front, while a new area of surface pressure falls ~~were~~ was over the central Carolinas. With the very strong flow aloft over the region, and the stronger surface flow noted along the coast of North Carolina, concern was increasing that perhaps severe thunderstorms could develop in the central Carolinas along the cold front. During this time, some thought was given to amending the AC to include a risk of severe further north in North Carolina and Virginia, however, considerable uncertainty still existed. The only thunder in this area appeared to remain behind the front, and there were no indications of development along the front from any of the remote sensors or surface observations.

0400-0500Z The cold front moved strongly through CAE with a well defined wind shift and pressure rise but no signs of convective development. The surface pressure changes indicated a strong rise over parts of Georgia into central South Carolina, while the pressure falls evident earlier over the central Carolinas lifted rapidly northeastward into the Delmarva. The lightning network, however, showed indications of thunderstorm development just east of CLT, suggesting that convection was forming near the front. By 0430Z, other CG strikes were noted into south central Virginia. Satellite imagery showed generally weak enhancement, although the cloud tops were slowly cooling. (The coldest tops were moving into the Delmarva area.)

We attempted to gain a radar view of the new development, but did not have much success. The Kavouras image from VQN was extremely noisy (which is very typical) and of little use, and attempts to manually dial-up VQN, ILM and RDU were not successful. Finally, an image was received from CLT depicting VIP1 cells along the front; however, rain at CLT indicated that the 5cm radar was probably attenuating. By 0445Z, an image from ILM was received which indicated only VIP2 cells along the front between CLT and RDU. This observation, combined with the retreating pressure falls and weak convergence along the front in North Carolina (no well defined wind shift or pressure rise was noted at CLT), suggested that while this situation needed to be closely monitored, a severe threat did not appear imminent.

0500-0530Z Satellite data at 0500Z indicated that the cloud tops were continuing to slowly cool over central North Carolina, but remained much warmer than the convection moving out of the Delmarva. Useable radar images were still not being received from VQN, even with data requests at 15 minute intervals. Surface data, however, showed signs of yet another pressure fall developing over eastern North Carolina (at least the third of the evening), and winds continued to gust along the coastal sections. During the period from

0500-0530Z, however, the lightning strikes diminished and became more diffuse along the front in North Carolina, suggesting that the convection might be weakening, while more organization in the lightning data was evident in southern Virginia.

0530-0610Z Radar and satellite data at 0530Z indicated convection between CLT and RDU was continuing to slowly increase, with cloud top cooling noted on one cell, and a VIP4 noted on the ILM coded message. Briefing of the midnight shift (Bob Johns) was now underway, with discussion focused on two possible threat areas during the early morning hours: northeast North Carolina into eastern Virginia, and parts of Florida (where a squall line along the front extrapolated into TPA by 09Z). The location of the strong winds aloft favored the northern area as the region that probably needed closer monitoring, even though the strongest cells (radar and satellite) were off the Florida west coast. Around 0600Z, a number of parameters appeared to be coming together. About this time, we received the first legible VQN radar image which depicted a line of thunderstorms from east of VQN into central North Carolina, with a VIP4 located immediately southwest of RDU. The ILM image was similar, with cell movement about 45 kt. The 0600Z satellite image now showed impressive cloud top cooling on the cell near RDU, and the 0600Z surface observation at RDU reported pressure falling rapidly and the wind backing (although the speed was only 8 kt). A look at the lightning monitor also indicated a significant clustering of strikes around the RDU cell that was not evident 30 minutes earlier. Around 0610Z, Bob suggested that the outlook be amended and we quickly settled on the threat area. Apparently, the cell near RDU became severe shortly thereafter.

Up until this time, the only special statement concerning thunderstorms in North Carolina was issued several hours earlier by CLT.

cc: Ed Ferguson

ACUS1 KMKC 271840
MKC AC 271900

CONVECTIVE OUTLOOK...REF AFOS NMCGPH940

VALID 271900 - 281200Z

THERE IS A SLGT RISK OF SVR TSTMS LT THIS AFTN AND TNGT TO THE RGT
OF A LN FM PNS 50 S MGM MCN CAE MYR...CONT...MRB 30 SE CTY.

GEN TSTMS FCST TO THE RT OF A LN FM 60 S MGY TUP BWG LEX CRW EKN
AVP BOS...CONTD...VRB FMY.

PRIMARY FOCUS FOR SVR TSTMS THIS AFTN AND TNGT IS OUTFLOW BNDRY
CURRENTLY ACRS SRN AL AND SRN GA. BEST MSTR CNVGNC AND INSTBY
WERE FOUND AT 18Z INVOF OF THIS BNDRY. RLTVLY STG WIND FIELD
AND MID LVL DRY PUNCH PROGD OVR SERN U.S. ARE ALSO FVBRL
PARAMETERS FOR SVR TSTMS. 500 MB COOLING FCST OVR SERN U.S.
THIS AFTN ALG WITH CONTD LO LVL MSTR ADVCTN WL FURTHER DESTBLZ
AMS.

..PHILLIPS.. 11/27/88
..PHILLIPS.. 11/27/88

```
MKCSIMMKC
TTAA00 KMKC 200530
MKC NWS/SFSS SIM BASED ON DATA THRU 05Z.  GRAPHIC SIM...CSM...AVAILABLE
BY 06Z IN AFOS.

SYNOPTIC...
MSTR CHANNEL SHOWS DRYG INCRG ACRS CNTRL/S TX INTO LA/MS WITH TROF BCMG
SMWHT SHARPER PER 12HR MDL TRENDS OVR E TX/LA.  MID/UPR LVL LOW HAS
CONTD MOVG/DVLPG EWD INTO NE WI.  HIER LVL TROF AXIS SEEN IN WATER
VAPOR IMAGRY EXTDS FM NE WI LOW THRU RFD - 30S UIN - TBN - FSM  TO CLL.
BULG IN HIGH CLDS OVR ERN GRT LKS/SE ONT SUGS STGST SPEEDS /140KT PLUS/
AT LIT/SLO ARE EXITG THRU SE ONT.

OH/TN VLYS TO CNTRL GULF COAST...
MID/LWR LVL TROF AXIS EXTDS FM VCNTY TCL TO BVE AND IS STARTG TO TURN
ENE JUST OVR 25KT.  WRN FRINGE OF MID/LOW CLDS WITH BACLIN BAND EXTDS
FM 35SSE LCK THRU ERN KY /40SW LOZ/ - HSV - 25SE NMM - 25NNW GPT TO
VCNTY BVE.  EDGE HAS EWD MOVMT 25KT ACRS KY..SLOWING TO EWD COMPONENT
JUST OVR 20KT ACRS AL.

LOW CLDS...
LOW CLDS ARE BNDD BY A CVG - BMG - 30NNW EVV - 20W MDH - 15E VIH - 25E
SZL - P35 - DSM LN.  WRN EDGE BCMS ILL DEFINED BUT IS ESTD FM DSM TO
MCW AREA - FRM - MSP TO DLH/HIB AREA.  EDGE HAS BEEN ERODG ACRS CNTRL/N
CNTRL IA PAST COUPLE HRS.  EDGE HAS SOME SWD COMPONENT ACRS SRN IL/ERN
MO AND APPRS IT WILL CLIP WRN KY IN A FEW HRS.  WRN EDGE HAS ESE MOVMT
JUST UNDER 20KT ACRS CNTRL PTNS MO/IA/MN.

GRT LKS...
UPR LOW IS NR GRB WITH CYC SHEAR AXIS EXTDG INTO ERN UPR MI BTN
SSM/PLN.  INITIAL AGL 500MB LOW PSN IS OFF BUT FCST 12Z PSN NR OSC LUKS
RSNBL.

NRN/CNTRL ATLANTIC COAST STATES...
LIGHTNING DATA SHOWS LINE CNVTN FM SE NY THRU SRN MD - ERN VA  INTO
CNTRL NC.  IR DATA SUPPORTS WITH CDR TOPS THRU THIS AREA.  CDST TOPS
ARE OVR EXTRM SE NY/NRN NJ.  LATEST DATA SHOWS TOPS COOLG WITH STG CELL
50NE RDU.  LATEST RAOB DATA SHOWS CSDRBL MSTR ADVCTG NWD ALG E COAST
WITH 8 DEGREE C DEW PTS AT 850MB DRAWN NWD INTO SRN NEW ENGLAND.

WY/CO/NRN AND CNTRL PLAINS...
RDG AXIS OVR NRN ROCKIES HAS LEE ENHANCED CI SPILLG SEWD ACRS WRN DAKS/
WRN KS AND OK PNHNDL.  SOME MID CLDS ARE SPRDG FM MT/WY INTO WRN DAKS
WITH STG WRM ADVCTN INDCD IN RAOB DATA.  TANSEY
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ACUS3 KMKC 280620
MKC MCD 280620

SELS MESOSCALE DISCUSSION FOR NC/DELMARVA...
CONCERNING... SEVERE THUNDERSTORM POTENTIAL

CLUSTER OF TSTMS VCNTY RDU IS ASSOCD WITH MSTR CNVGNC CNTR/MESO LOW.
S WINDS 30 KT ARE FEEDING NWD AND OF CLUSTER.  MOVMT HAS BEEN 240/45.
THIS EXTRAPS TO 50N GSO ARND 07Z AND MOVG INTO SE VA ABT 40WSW ORF
ARND 08Z.  WW IS NOT ANTICIPATED HWVR LOCAL OFFICES SHD MONITOR THIS
FEATURE AS IT CONTS ENE TWD SE VA.

..BECKMAN.. 11/28/88
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ATTACHMENT 1

NORTH CAROLINA TORNADO OUTBREAK
November 28, 1988

Approximate Chronology - WSFO Raleigh

Note: This preliminary chronology was initially prepared the day of the outbreak and updated over the next two days as additional details came to light. Some entries and times may yet prove to be incorrect Many of the listed times are estimates. Chronology is incomplete.

Staff on duty:

| | | |
|---|---|---|
| Lead Forecaster and Shift Supervisor working Public Forecast Desk......... | Jan Price | 00-08am |
| Forecaster working Aviation Desk..... | Richard Jones | 00-08am |
| Weather Service Specialist........... | Susan Yeaman | 00-08am |

Acting Area Manager,Joe Pelissier was called about
2:05 am and arrived about 2:35am

| Time (EST) | Item |
|---|---|
| 0015 | Volens reminded that RDU radar still out of service.<br>Volens and other radar displays were dialed on RADID at various times through the night. Occasional difficulty in obtaining image due to sweep interrupt while doing vertical scan. |
| 0100 | Approximate time of initial tornado touchdown in Raleigh near Duraleigh Road and US-70W. |
| 0105 | Fairly reliable estimate of time tornado reached Sawmill Rd. and Mine Shaft Dr., near Leadmine Rd. (supplied later by Forecaster, Jim Brackett, who lives in the area). |
| 0115 | Tim Drum, CP&L Meteorologist, calls and talks to SY. Reports that he heard a loud wind noise and there appears to be considerable damage. He said a downburst or tornado might have occurred. |
| 0115 | Lead Forecaster gets call on NAWAS (from Wake Co. Sheriff or Hwy. Patrol) asking about possibility of severe weather and the reporting wind damage. |
| 0116 | LF calls VQN for radar update. VQN reports strong cell moving rapidly NE across Wake Co., top lowering. |
| 0118-onward | Calls begin flooding all telephone lines with reports of damage, possible tornadoes, etc. from various points in N. Raleigh. |
| 0118 | LF begins preparing Special Weather Statement describing reports and indicating possible tornado. All three on duty take phone calls. |
| 0128 | SELS Mesoscale Discussion...Concerning Severe Thunderstorm Potential...WW not anticipated. |

Page
Acc.

0135 SPS transmitted. Also put on NWR.

0140 LF requests forecaster to begin preparing Tornado Warning for Franklin Co. while he calls VGM for update.

0145 Franklin Co. TOR on NWR.

0148 TOR for Franklin Co. issued.

0156 Tornado touchdown in Franklin Co. at US401 and NC58 (from HWY Patrol Log received later).

0158 MKCAWW for Tornado Watch 512 issued by SELS.

btwn Tim Drum calls back after investigating damage. He said CP&L
0145 has a transmission line stressed for 115 mph which was still
and standing but there was a lot of other damage and he concluded
0215 that it was probably a downburst.0215

0200 Electric clock stopped in Ita Community, Halifax Co. and another stopped in Aventon, Nash Co.

0203 TOR for Halifax Co. issued.

0203 Tornado Watch 512 for NE N.C. issued by SELS

0204 Another electric lock stopped in Ita Community, Halifax Co.

0206 Halifax TOR on NWR.

0205 LF notifies DMIC.

0212 Watch called to NAWAS.

0212 Watch transmitted on AFOS to NWW.

0214 Redefine Statement transmitted.

0215 Tornado touched down near NC56 and NC58 in near Castalia in Nash Co. (report received later on NAWAS).

0224 Tornado touchdown reported in Ita Community of Halifax Co. (from NCHP log later).

? Apparent tornado damage in Occoneechee Neck area of Northampton Co. just east of Halifax.

0225 Watch broadcast and alarmed on Durham and Tarboro NWR.

0235 DMIC arrives.

0240 EBS activated for watch on WRDU.

0250 EBS activated for watch on WTRG.

0343 SELS clears western part of Watch 512...WSFO RDU clears Warren and Franklin Counties only.

0524 SELS issues Tornado Watch No 513 to replace 512, covering most of coastal plain and coast. Secondary upper short wave triggering new development.

0527 Watch sent on AFOS and NAWAS.

0533 Redefine Statement for 513 transmitted.

0550 HAT issues tornado warning for Northeastern Dare Co.

In addition to above actions, staff were occupied with routine forecast issuances and amendments, observations, NWR, and a constant stream of calls from officials, media and public.

National Weather Service
Employees Organization
AFFILIATED WITH MEBA AFL-CIO

820 Chip Circle
Cary, NC 27513

March 29, 1989

James H. Scheuer, Chairman
House Subcommittee on Natural Resources,
Agriculture, Research, and Environment
H-2-388 HOB Annex 2
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

On behalf of the National Weather Service Employees Organization (NWSEO), and as an NWS forecaster assigned to the Raleigh, NC Forecast Office, I appreciate the opportunity to provide comments following the March 3, 1989 Field Hearing on Tornado Forecasting and Severe Storm Warning.

Many of the Findings and Recommendations of the National Weather Service's February, 1989 Natural Disaster Survey Report of the November 28, 1988 North Carolina Tornadoes address one of three areas: communications problems, NWS staffing problems, or equipment (outages and out-dated). Finding 1 of that Report addressed perhaps the most critical, that of staffing problems. Finding 1 stated, "prolonged vacancies and training time needed for new employees" as the reason for an approximate 25% cutback in preparedness activities by the Warning Preparedness Meteorologist at the Raleigh WSFO between 1985 and 1988.

You may recall an earlier Subcommittee hearing on October 18, 1984 in Rocky Mount, NC regarding tornado prediction and preparedness. Similar problems were cited at that hearing and in the July, 1984 NOAA Disaster Survey Report of the March 28, 1984 Carolina Tornado Outbreak. At the 1984 hearing, as in the March 1989 hearing, it was noted that staff shortages are not restricted to the offices in the Carolinas, but indicative of problems nationwide.

Perhaps Dr. Edward A. Brotak, Associate Professor in the Atmospheric Sciences Program at the University of North Carolina (UNC) at Asheville summarized it best in his written testimony (p.5) to the Subcommittee on March 3, 1989 in Raleigh:

> "The best way to prevent losses due to severe weather is to have fully-staffed NWS offices equipped with the latest technology to protect the population. Unfortunately, in recent years, just the opposite has occurred. Mandated budget cuts have severely hampered the NWS's ability to perform its duties. Many NWS offices around the country are seriously understaffed. The procurement of new equipment has been delayed or abandoned.

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> One good example of this is the situation with our weather satellites. These satellites provide some of the first indications of developing storms. To adequately cover the United States, we need two geostationary weather satellites. . . Recently, GOES West failed, leaving just the single satellite to provide continuous surveillence (sic). There is no back-up, and no new satellite launchings are planned for over a year. It is quite possible that the remaining GOES East satellite will also fail before new satellites are ready. This will leave us with only polar orbiting satellites which only provide imagery several times a day rather than continuously. This will be of no benefit for severe weather forecasting. . .
>
> The main duty of the NWS is the protection of life. There is no doubt in my mind that if budget cuts continue and services have to be further reduced, that loss of life will result. The situation which occurred in Raleigh last November will become more common. The legal and societal consequences of these events will likely be much more catastrophic than is obviously imagined in Washington."

There is a fallacy in the assumption being circulated by the NWS that by gaining more technology, staffing levels can be reduced. There is no simple technological fix to the complexities of predicting severe weather events on the horizon. In the 1980's, the NWS has had a history of understaffing it offices. This must not continue. For the 1990's, Weather Forecast Offices must be adequately staffed by fully trained personnel qualified in the operation and interpretation of the new technologies.

We hope that the Subcommittee will continue, as it has during the 1980's, to be diligent and persistent in it's oversight work of the National Weather Service. We recommend that the Subcommittee review closely the recently submitted NWS's Strategic Plan for the Modernization and Associated Restructuring of the National Weather Service and the National Implementation Plan for the Modernization of the National Weather Service that is to be released by the NWS in October.

We commend Congressmen David Price and Tim Valentine, their staffs, and the Subcommittee staff, for assisting in the conducting of a thorough public hearing on March 3, 1989 in Raleigh. In addition, we applaud Mr. Ronald McPherson, Deputy Assistant Administrator for Weather Services of NOAA, for his frank comments and observations at the hearing.

Sincerely,

Herbert L. White

Herbert L. White
Chairman, Region 1

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